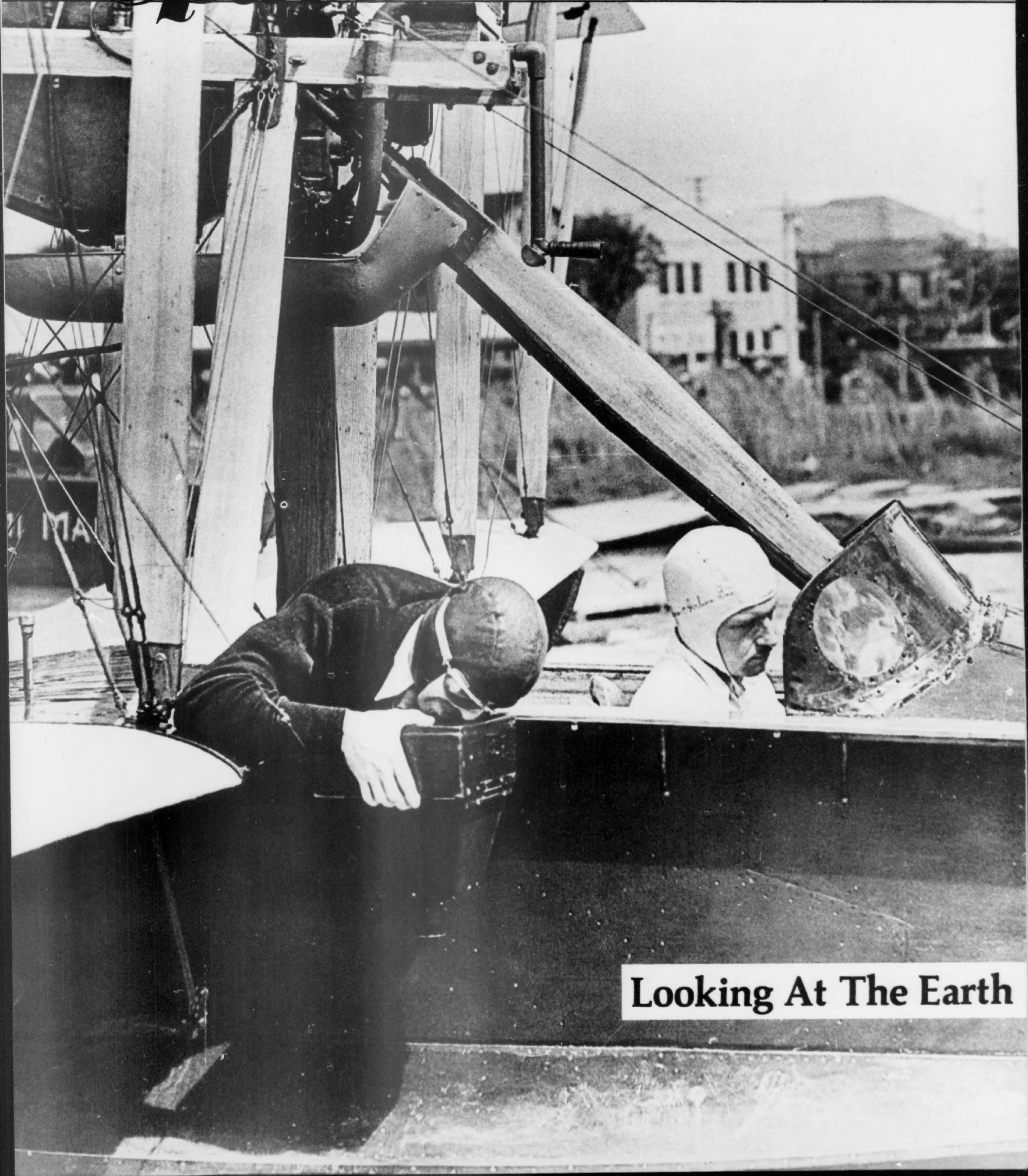
Air & Space

National Air & Space Museum
Smithsonian Institution

Vol. 5, No. 3 Spring 1982



Looking At The Earth

National Air and Space Museum
Noel W. Hinners, *Director*
Walter J. Boyne, *Assistant Director, Resource Management and Operations*

Education Services Division
Janet K. Wolfe, *Chief*

Air & Space
Linda S. DuBro, *Editor*
Holly Haynes, *Editorial Assistant*

Air & Space, a mini-magazine for educators, is published four times during the school year as an outreach of the National Air and Space Museum, Smithsonian Institution, Washington, D.C.

Air & Space combines information from many sources for a condensed overview of the history, science, technology, and social impact of selected aviation and space subjects.

Air & Space
Address all communications to: *Air & Space,* Room P-700, Education Services Division, National Air and Space Museum, Smithsonian Institution, Washington, D.C. 20560. For changes or corrections of address, write to *Air & Space* at the above address, and include the 6-digit subscription number on your mailing label.

There is no charge for *Air & Space.* The magazine is not available by paid subscription.

Air & Space may be freely photocopied for classroom use. Commercial interests and other publications wishing to reprint material should mail requests to the above address.

Back issues of *Air & Space* are available on microfiche or photocopy through University Microfilms International, Inc., 300 N. Zeeb Road, Ann Arbor, Michigan 48106.

MUSEUM HOURS
Through Labor Day (September 7), the Museum will be open 10 a.m. to 9 p.m. From September 8 to March 31, hours are 10 a.m. to 5:30 p.m. The Museum is open to the public every day of the year except Christmas. Admission is free.

For brevity, the National Air and Space Museum is often referred to in these pages as NASM. The National Aeronautics and Space Administration is NASA.

Front Cover: Photographer Richard B. Hoit demonstrating how his homemade camera was held out over the side of the seaplane in order to get vertical shots for mapping from 1500-1800 m (5000-6000 ft.). Pilot George Rummel sits in the Curtiss flying boat.

Briefing

Looking at Earth—Storm Warnings

Noel W. Hinners
Director, NASM

The advent of earth-viewing satellites has contributed immensely to an improvement in the quality of life. This is most obvious in the area of weather forecasting, hurricane tracking, severe storm warning, and in communications where one can now view live TV from almost anywhere in the world or talk static-free to friends continents away. Less obvious are the potential contributions to be made by remote-sensing satellites, such as Landsat, to such diverse fields as land use and geologic mapping, oceanography, oil and mineral exploration, and crop assessment. Much less well known for reasons of classification, but demonstrated beyond doubt, are the contributions made to our national security by reconnaissance satellites. This kind of use rapidly boils down to the argument "if you know what they're up to, there is less danger of the element of surprise being an advantage to a potential enemy."

Until recently most of the Earth-viewing activities, by many nations, have proceeded relatively unhindered. Weather information is freely exchanged, and communication satellites are commercially available to whomever can afford them. Landsat remote sensing has been viewed as largely a research activity, and reconnaissance systems have been accepted as defensive in nature. There is reason to believe, though, that the "good old days," marked by technological development and demonstration, are about to vanish.

There is a limit to how many communications satellites one can place in the preferred equatorial geosynchronous orbit for reasons of "your broadcast beam is interfering with mine." Some equatorial nations are claiming sovereignty over the "space" above their countries. Technological solutions to the problem are possible and are being worked on, but meanwhile political solutions must be pursued.

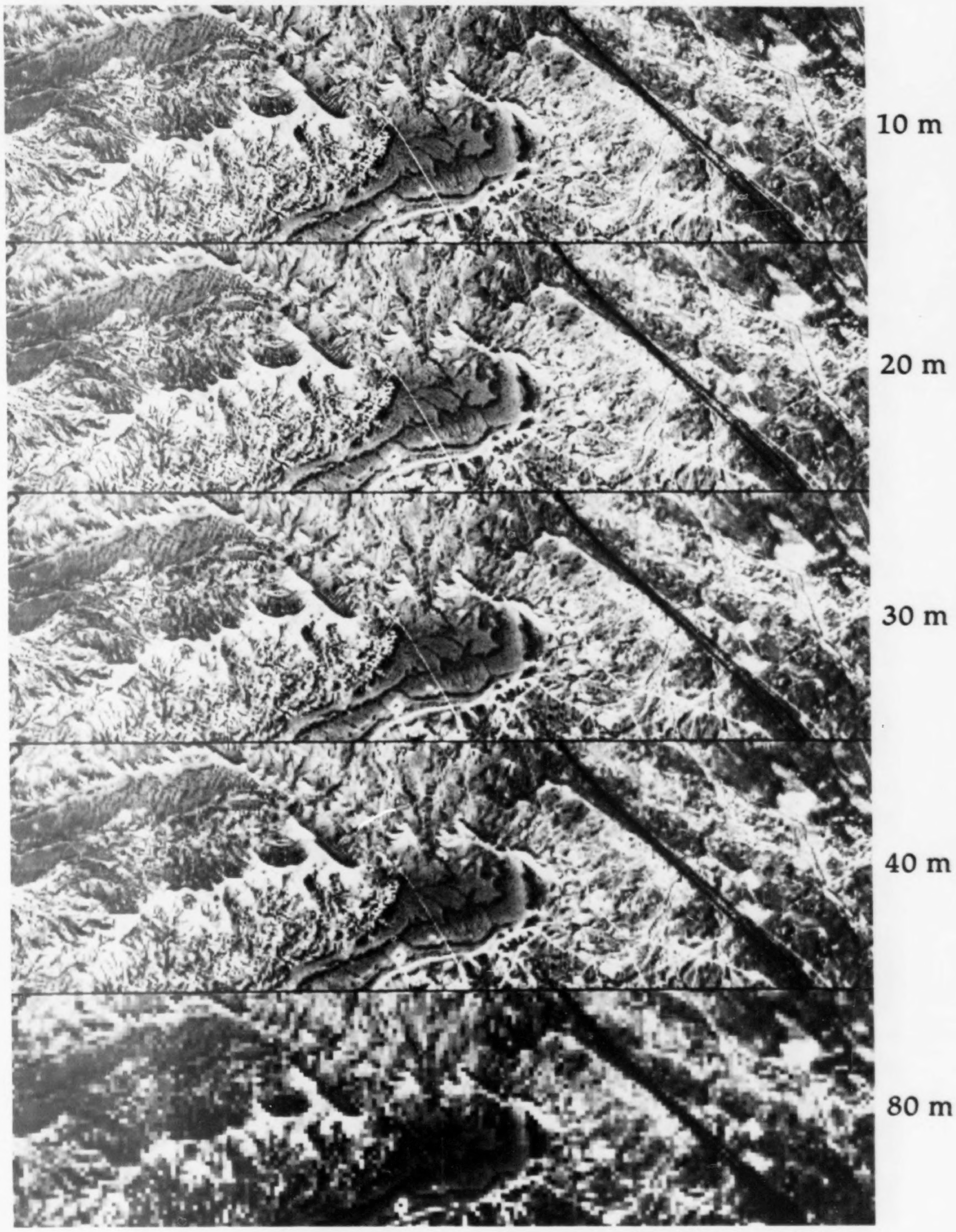
Remotely sensed data from Landsat has been used mainly for research but does indeed have potential commercial applications. This raises serious political issues: Does a satellite operator have the right to data taken over foreign countries? Should "sensed" nations have guaranteed access to "their" data? (at what price?) Are the touted benefits of Landsat images real only as long as NASA pays for the development, operations, and data distribution or will those benefits disappear if the users are charged the actual cost? The U.S. government is taking the position that future Landsats (after the Landsat-Ds) will be owned and operated by private enterprise. The economics make it doubtful that commercialization is a viable alternative, leading one to the conclusion that the United States might abandon Landsat-type operations in the mid- to late-80s. Meanwhile, the French are preparing to operate an equivalent satellite, called SPOT, as a government-subsidized operation.

One can enumerate many more potential problems, including development of anti-satellites whose task, clearly offensive, is to destroy the other guy's reconnaissance or communications satellites. By now, I hope I've convinced you that the decade of the 80s may be significant more for its policy-related actions, relative to viewing the Earth, than for the new technological developments. This is not an unusual situation—most technologies bring social/political problems. It is important that students gain an appreciation for this and learn to participate in the solution. I hope that some of you will involve your classes in discussion of these issues.

Frederick J. Doyle
Research Cartographer
U.S. Geological Survey
President, International Society for
Photogrammetry and Remote Sensing

Mapping from Air and Space

Simulation of Varying Spatial Resolutions



Pixel (picture elements) in Meters

"What is a map?" Until a few years ago a proper answer to the question would have been, "A map is a graphical representation of information about a portion of the Earth's surface." However new developments in mapping science in the last two decades have made that answer inadequate. Although most maps are still compiled using lines and symbols to represent the information about the Earth's surface, new techniques have made it possible to produce maps that also include a photographic image. Such an "orthophoto map" contains much more detailed information, but it also requires that the map user be able to interpret the photographic image. It is usually necessary to add some lines and symbols to make the map content clear. Maps with a photoimage base are becoming increasingly popular for a great many applications.

Scale and Resolution

One of the fundamental characteristics of a map is its scale, which is defined as the ratio of a distance on the map to the distance that it represents on the surface of the Earth. This is usually written as a fraction 1:S. On a map at scale 1:1,000,000, for example, a distance of 1 mm on the map represents 1 km on the Earth's surface. At this scale it would not be possible to graphically represent the pattern in an urban area where streets might be only about 100 m (328 ft.) apart. Thus the amount of information that a map can present is directly related to its scale. For most countries in the world, a standard map scale for uniform coverage is 1:50,000, and 1 mm on the map represents 50 m on the ground. In the United States, where metric units are not yet in common use, the standard national map scale is 1:24,000; 1 inch on the map represents 2000 feet on the ground.

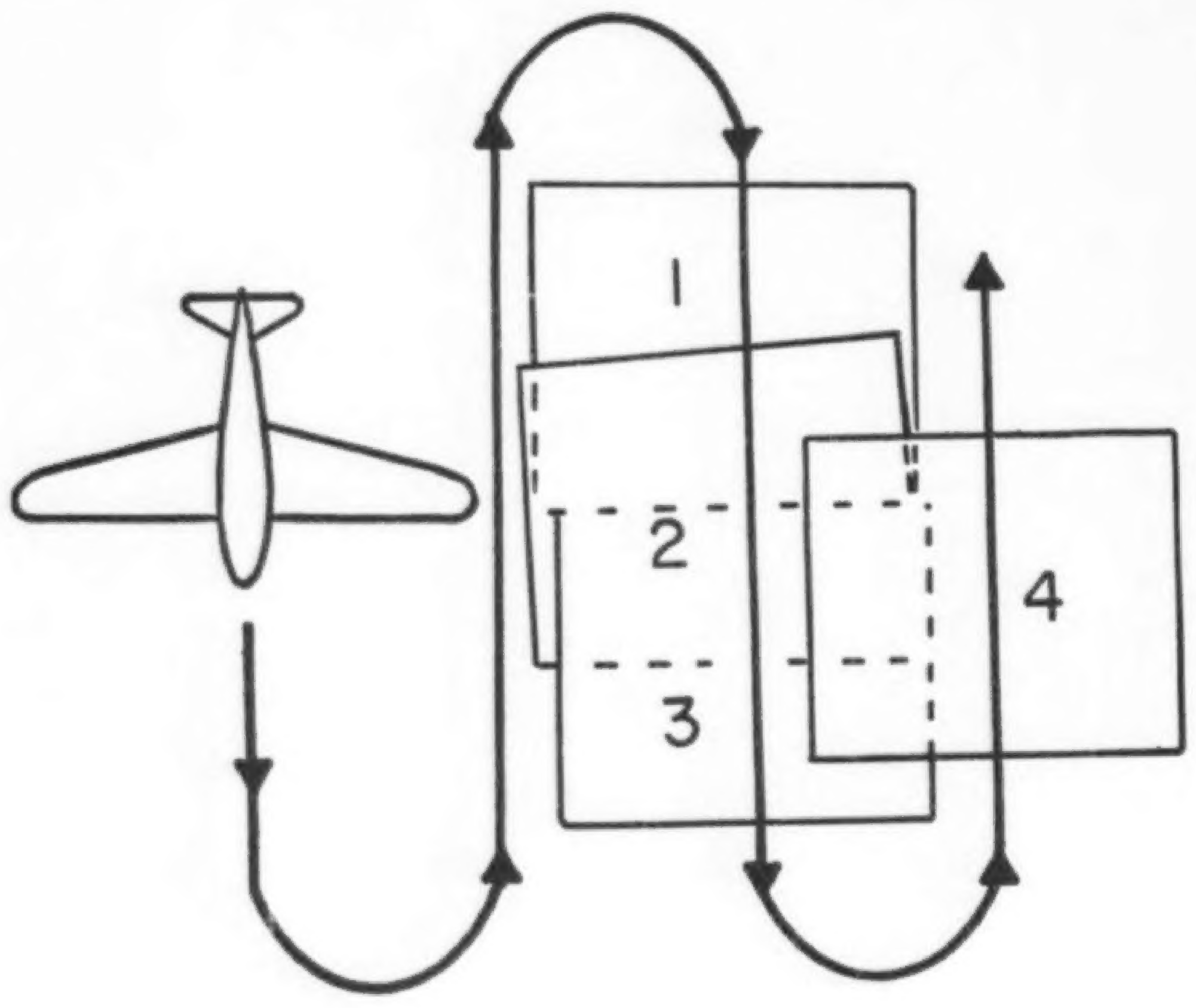
Information presented by a photographic image as a function of its scale is measured in terms of "resolution"—the smallest distance between two components of an image that can be seen by the naked eye at the usual reading distance of about 25 cm. Resolution is measured in line pairs per millimeter (1p/mm), and the eye can see about 7 1p/mm. If a photoimage map is reproduced at a scale of 1:24,000, the eye can see 1/7 mm times 24,000, which is a little less than 3.5 m on the ground. Most continuous-tone photographs can resolve much more than 7 lp/mm. A photograph with 35 lp/mm, for example, could be enlarged five times.

The Large Format Camera (LFC) has a ground resolution of about 10 m (black-and-white film) to 25 m (color film), providing fine spatial detail and geometric qualities that are required for topographic mapping. However, the LFC does not provide digital data on the spectral signatures of the Earth's surface materials.

Mapping from the Air

For aerial mapping, a network of "ground control points" are established by ground surveying techniques. Both the position and elevation of these points must be known in the geographic coordinate reference system adopted for the map. The details between these points will be filled in from aerial photographs; all mapping is essentially interpolation.

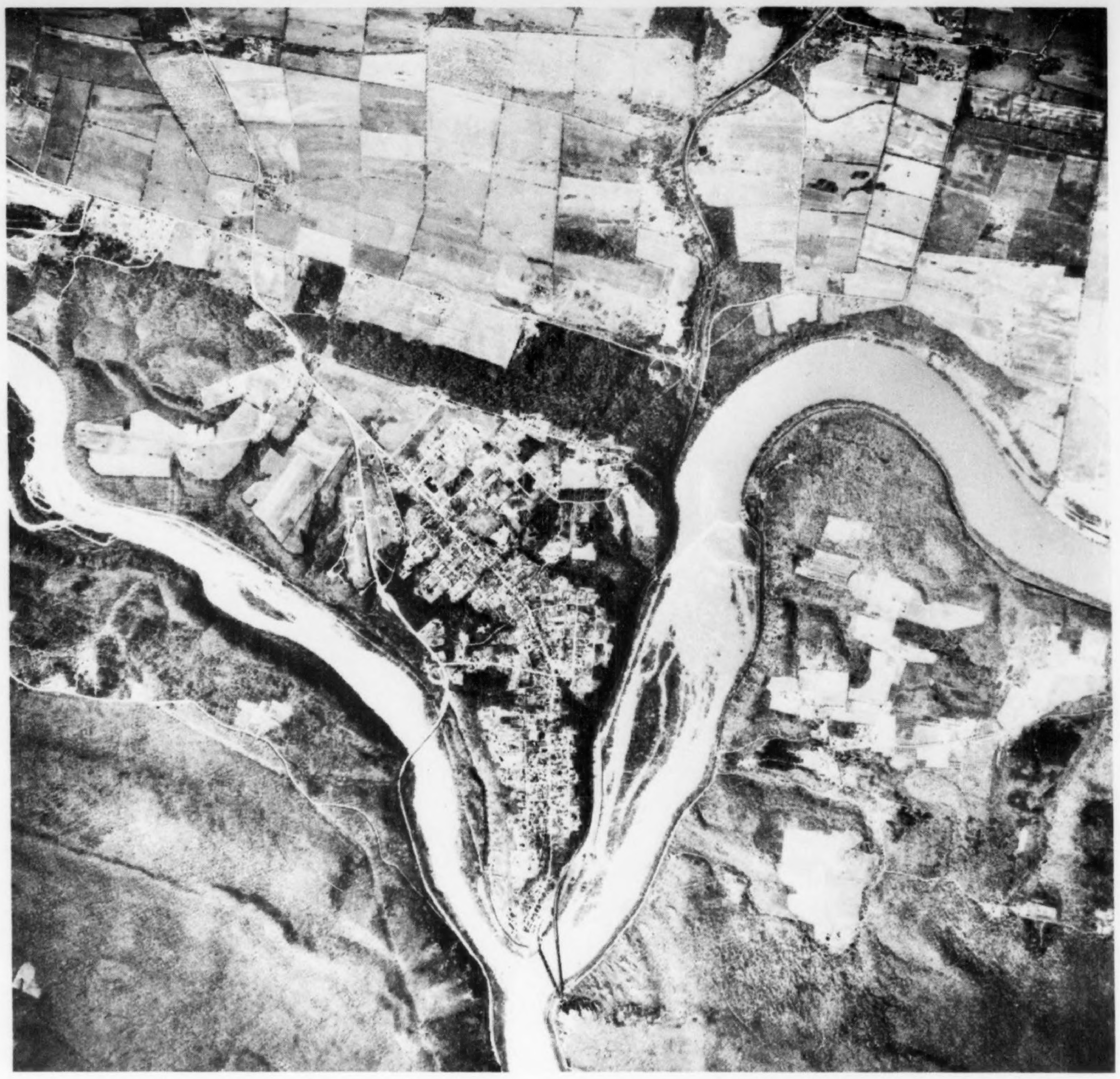
The pattern of coverage for aerial photographs is critical to the mapping operation. An aircraft flies a series of parallel flight lines. Along each flight line pictures are taken at intervals so that each photograph will overlap the preceding one by 60 percent. The spacing of flight lines assures that one strip of photographs has about 20 percent side-lap with the adjacent strip. This pattern not only assures continuity of coverage, but it also makes it possible to determine the position of features and their elevation.



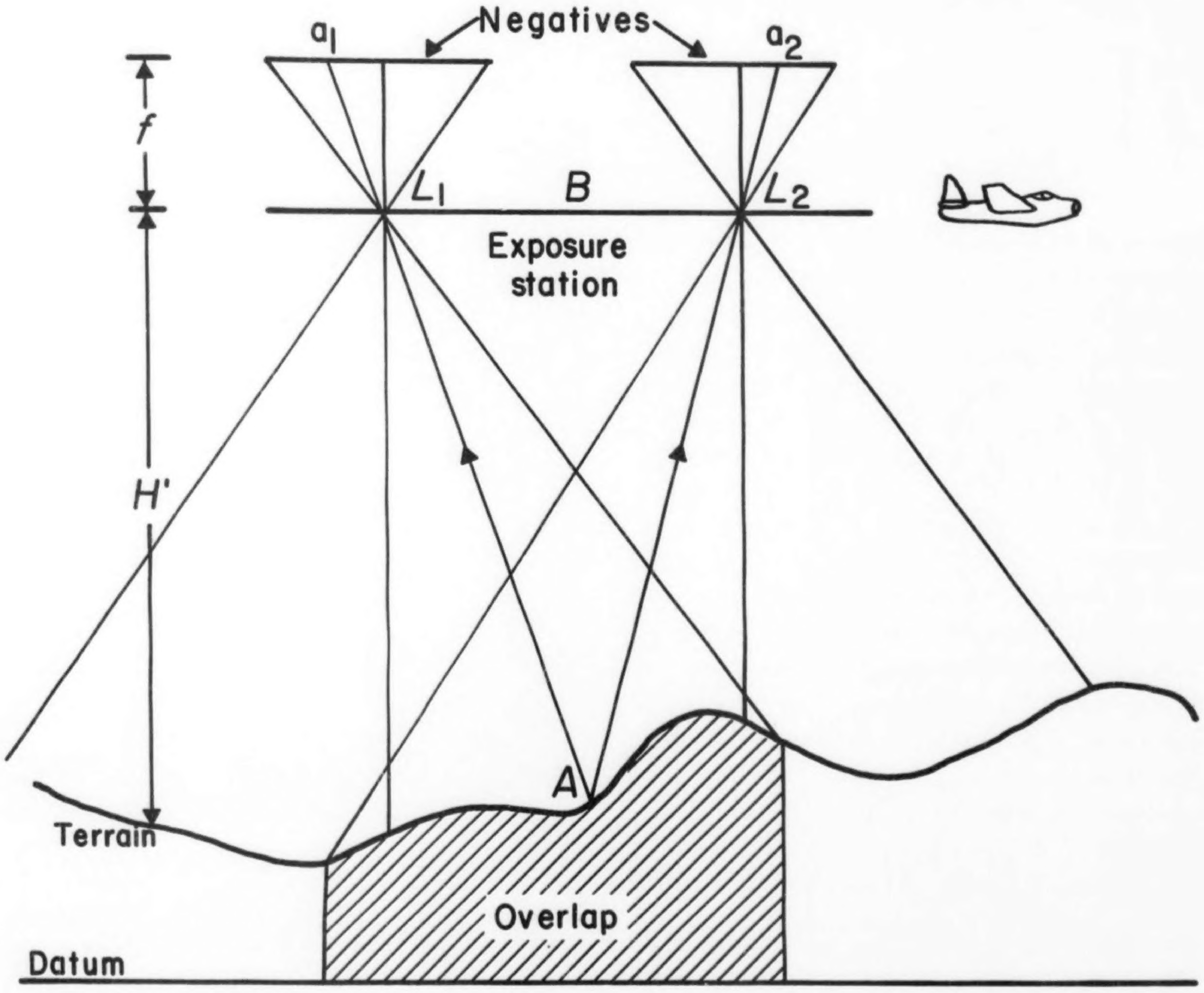
The flight pattern for aerial photographs assures continuity of coverage for an area to be mapped. It also assures that each point on the ground is photographed from at least two adjacent exposure stations. This provides the stereoscopic effect, which makes it possible to map topographic elevation as well as planimetric position.

The mapping camera is a precise instrument—usually with a focal length (lens to film distance) of 15 cm and a picture format of 23 x 23 cm. When it is mounted in a moving aircraft—subject to vibrations from the engine and photographing through the atmosphere—the resolution of the photographs is about 30 lp/mm. Also, although a vertical photograph looks like a map, it is not possible to fly the aircraft absolutely straight and level. The resulting tilts in the photographs introduce distortions that must be removed. These distortions are removed by photogrammetric procedures—mapping from photographs.

Within the area covered by two adjacent photographs, every point on the terrain is seen from two different exposure stations. When the photogrammetrist examines these photographs, he uses a stereoplotting instrument that presents the image from one photograph to his left eye and from the adja-



Aerial photograph of the junction between the Potomac and the Shenandoah Rivers at Harper's Ferry. At this scale, cultural features such as roads, bridges, and housing communities are clearly visible. The patterned area at the top represents fields.
Photo scale: 1:24,000; Focal length: 6 in.; Date flown: March 28, 1965; Courtesy U.S. Geological Survey



A terrain point A is photographed from two exposure stations L_1 and L_2 producing image points a_1 and a_2 on the two overlapping photographs. The scale of the photographic image is f/H where f is the camera focal length and H is the flight altitude. By measuring on the photographs the locations of a_1 and a_2 it is possible to determine both the position and elevation of the ground point A.

cent photograph to his right eye. This creates a three-dimensional or stereoscopic view of the terrain, which is much like the old parlor stereoscopes or 3-D movies. The horizontal relationship of the features can be seen as well as the vertical relationships such as hills and valleys, the slope of streams, the heights of buildings and trees, etc. This stereoscopic effect follows strict geometric rules so that it is also possible to accurately measure the horizontal positions and the elevations of all features seen in the photographs. In the stereoplotting instrument, two overlapping photographs are placed on carriers supported by a 2-axis system. This permits the photographs to be rotated to reproduce the tilt of the camera at the time the picture is taken. The rays of light from the image-point through the lens to the ground-point are simulated by space rods. The intersection of these two rods represents the position of the point on the ground. If the aerial photograph has a resolution of about 30 lp/mm, it contains more information than the operator can see with the naked eye. Therefore the optical system provides a magnification that should be at least 30/7 = 4+. The lower part of the instrument, called the base carriage, can move in the three-dimensional XYZ coordinate system of the map. As the operator moves the base carriage, the space rods carry the measuring marks over the plane of the photographs, permitting the operator to measure the position and elevation of each point.

In operation, the photogrammetrist first identifies the location of the surveyed ground control points on the pictures. By adjusting the instrument he makes the images of those points coincide with their true positions at the map scale. The base carriage is connected to a drawing table where the actual lines are compiled. In this way, the operator is able to draw all of the features in their proper location and is able to compile contour lines giving the terrain elevation.

For standard 1:24,000-scale mapping, photographs are taken at an altitude of about 12 km above the terrain. With a camera lens of 15 cm focal length, the scale of the photograph is about 1:80,000. At this scale the 30 lp/mm resolution of the photographs means that one can detect objects about 2.7 m on the ground. This resolution is required to see roads, railroads, buildings, and other cultural features that are normally found on maps. Also the allowable theoretical magnification of the photographs would be 30/7 = 4+. This is more than adequate to accommodate the 3.3 enlargement between the 1:80,000-scale photographs and the 1:24,000-scale maps.

Ninety percent of modern mapping is performed by photogrammetric procedures. For maps at various scales, it is the photogrammetrist's job to work out the relationship between camera characteristics, airplane flight lines, photo and map scales, and instrument compatibility.

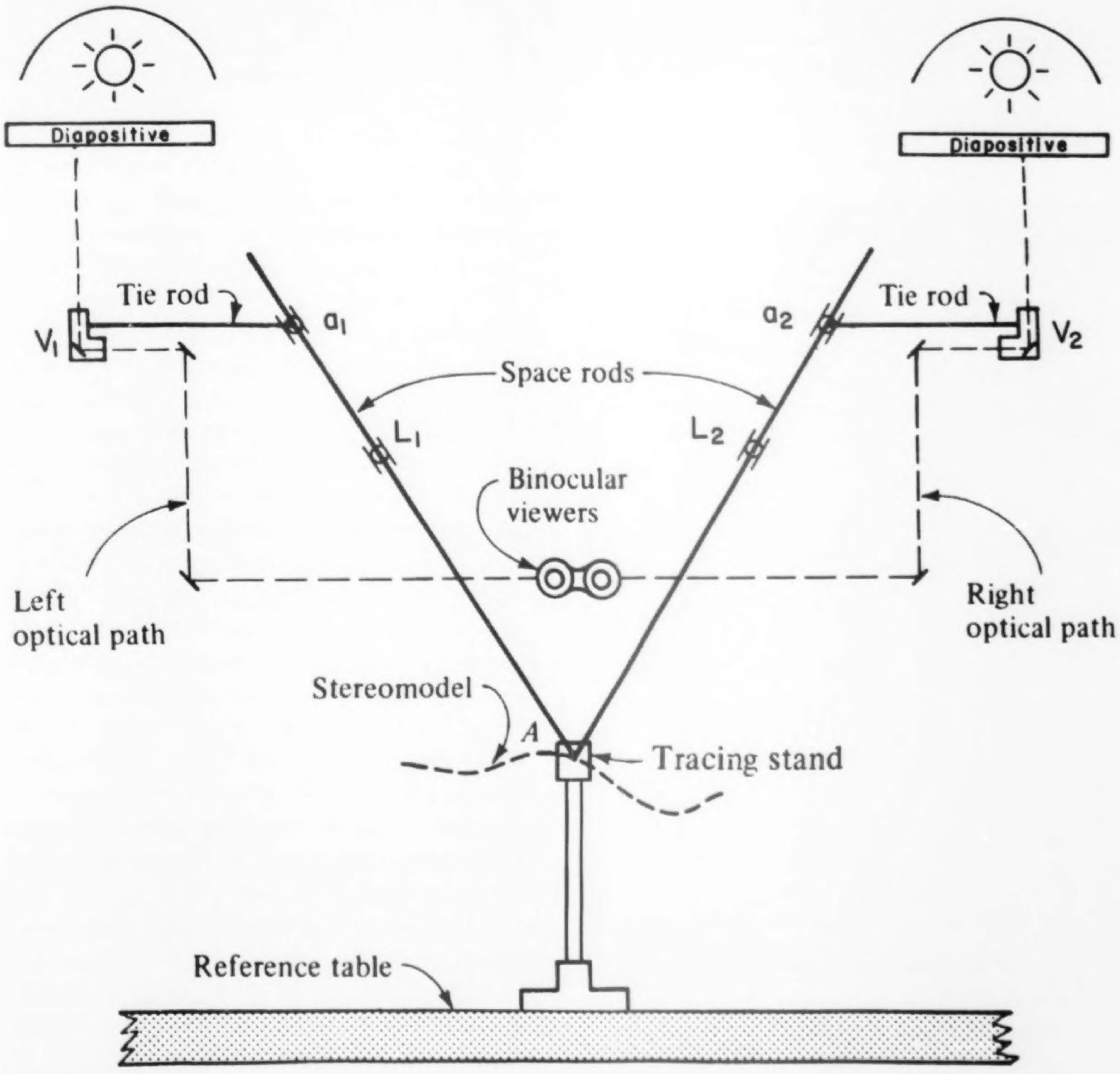
Mapping from Space

From the earliest days of the space program, cartographers have expected that photography from space vehicles would result in the same increment of productivity that came about when aerial photography replaced ground surveys. There is little economic justification for flying a space system to map limited areas. One needs to be concerned with areas of subcontinental size. Such areas, which do not already have reasonably accurate maps, are mainly found in developing nations. However, because most of these areas do not have a basic survey, ground control points are not available to provide position and elevation data for photogrammetric mapping. With precise location of exposure stations and determination of the attitude of the cameras at the moment of exposure, the need for ground-control points can be eliminated.

In the United States, NASA and the Department of Defense are developing the NAVSTAR Global Positioning System. This system will consist eventually of 18 communication satellites located in six different orbital planes, so that it will always be possible to see at least four spacecraft from any point on Earth or in near-Earth orbit. By monitoring the signals received from the NAVSTAR satellites, it will be possible to determine the location of a spacecraft with an accuracy of less than 10 m in all three dimensions. Also, photographic and electro-optical star sensors are being developed, which will make it possible to determine the attitude with an accuracy of a few arcseconds. This combination of precise position and attitude data can virtually eliminate the need for ground-control points in mapping from satellite images.

In 1972 NASA launched Landsat-1, followed by Landsat-2 in 1975, and Landsat-3 in 1978. Instead of film cameras, these spacecraft carried scanning electro-optical sensors that recorded the Earth scene with an equivalent ground resolution of about 200 m. The geometry of the Landsat system does not provide suitable stereoscopic coverage, so it is impossible to determine terrain relief from Landsat imagery. Their use, therefore, is for looking at gross features—

Basic Principles of Mechanical Projection



Diapositives are placed in carriers and illuminated from above. Two space rods are free to rotate and slide up and down through joints at L_1 and L_2, which are representative of the aerial camera lens. The space rod allows the lenses V_1 and V_2 to be moved by means of tie rods connected at a_1 and a_2, which represent the image point. The space rod represents the ray of light from the terrain point, A, through the lens (L) to the image point (a). The optical system permits the operator to scan the stereoscopic model produced from two overlapping photographs.

large field patterns, forested areas, geologic structures, etc.—rather than for standard topographic mapping.

In the summer of 1982, a fourth spacecraft, Landsat-D, will be placed in orbit. The ground resolution of this system has been increased to an equivalent of 75 m, but it will still not address topographic mapping.

The U.S. Geological Survey has proposed an electro-optical system called MAPSAT, which would overcome some of these shortcomings. The sensors would be three multi-spectral linear arrays, one looking 23° forward, one vertical, and one 23° aft. This configuration would provide useful stereoscopic coverage, so that terrain relief could be determined and would produce data with an equivalent ground resolution of about 25 m. The spacecraft would have the Global Positioning System to locate the images with sufficient accuracy. It would also have an electro-optical stellar reference system to provide continuous data on the spacecraft attitude. This system would be able to meet the geometric requirements for mapping at 1:50,000 scale with a contour interval of 25-40 m. However the ground resolution would be more suitable for reproduction as an image map at scale 1:150,000 and would not adequately record cultural detail.

A major advantage of the Space Shuttle is that the Orbiter vehicle returns to Earth after each mission. This makes it suitable for film-cameras that require the film to be returned to Earth for processing, rather than transmitting the information from the spacecraft to ground stations. Two different cameras are being built for mapping from space.

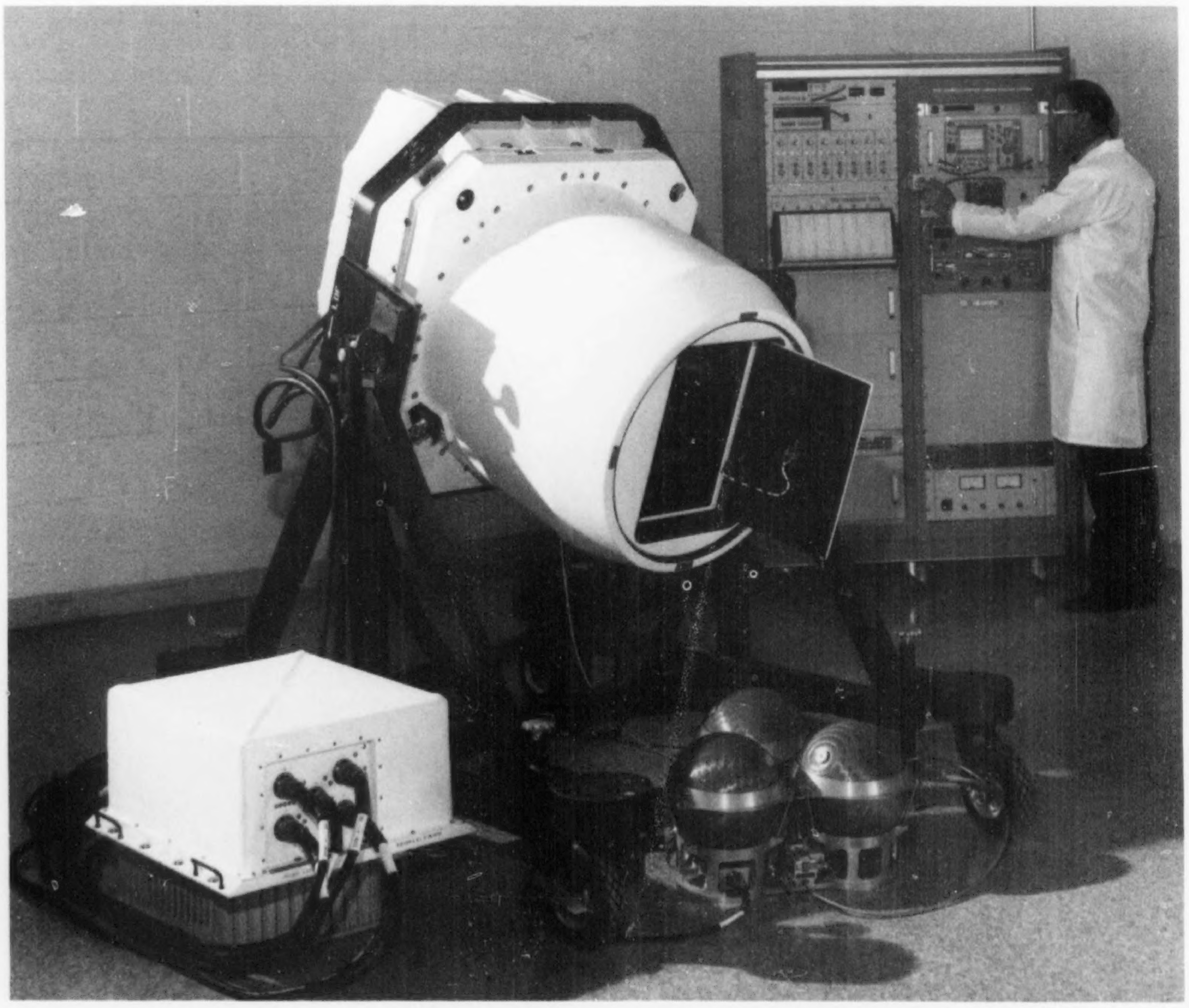
Spacelab-1 is a joint venture between the European Space Agency and NASA. It is presently scheduled for Shuttle mission 9 in September 1983 at an altitude of 250 km. Among many experiments in Spacelab is the Metric Camera, which is a modified Zeiss aerial camera having 30.5 cm focal length and 23 x 23 cm film format. Because a spacecraft in orbit is not subject to the vibrations and attitude perturbations of an aircraft, it is possible to achieve much higher resolution than with the same camera in an aircraft. This Metric Camera will be capable of producing ground resolution at approximately 20 m/lp. The pictures will be reproducible as an image map at scale 1:150,000 but will not show cultural detail with complete consistency. The system will provide good stereoscopic coverage, which will permit contour intervals of about 40 m to be compiled. However, because Spacelab will not have the Global Positioning System or a suitable attitude reference system, it still will be necessary to employ ground control points in order to make maximum use of the Spacelab photographs. Nevertheless, the metric camera photographs will be a long step forward in topographic mapping from space.

NASA is building its own photographic system for use in the Shuttle. A new mapping camera, referred to as the Large Format Camera (LFC) has already been built and readied. It has a focal length of 30.5 cm and a film format of 23 x46 cm (hence the designation large format). NASA is also building a stellar attitude reference system for use with the LFC. By post-flight measuring of the identified stellar pattern, it will be possible to determine the attitude of each LFC photograph with an accuracy of about 5 arcseconds. Adequate accuracy in the location of the exposure-station position depends upon adding the Global Positioning System to the payload package, but this has not yet been approved.

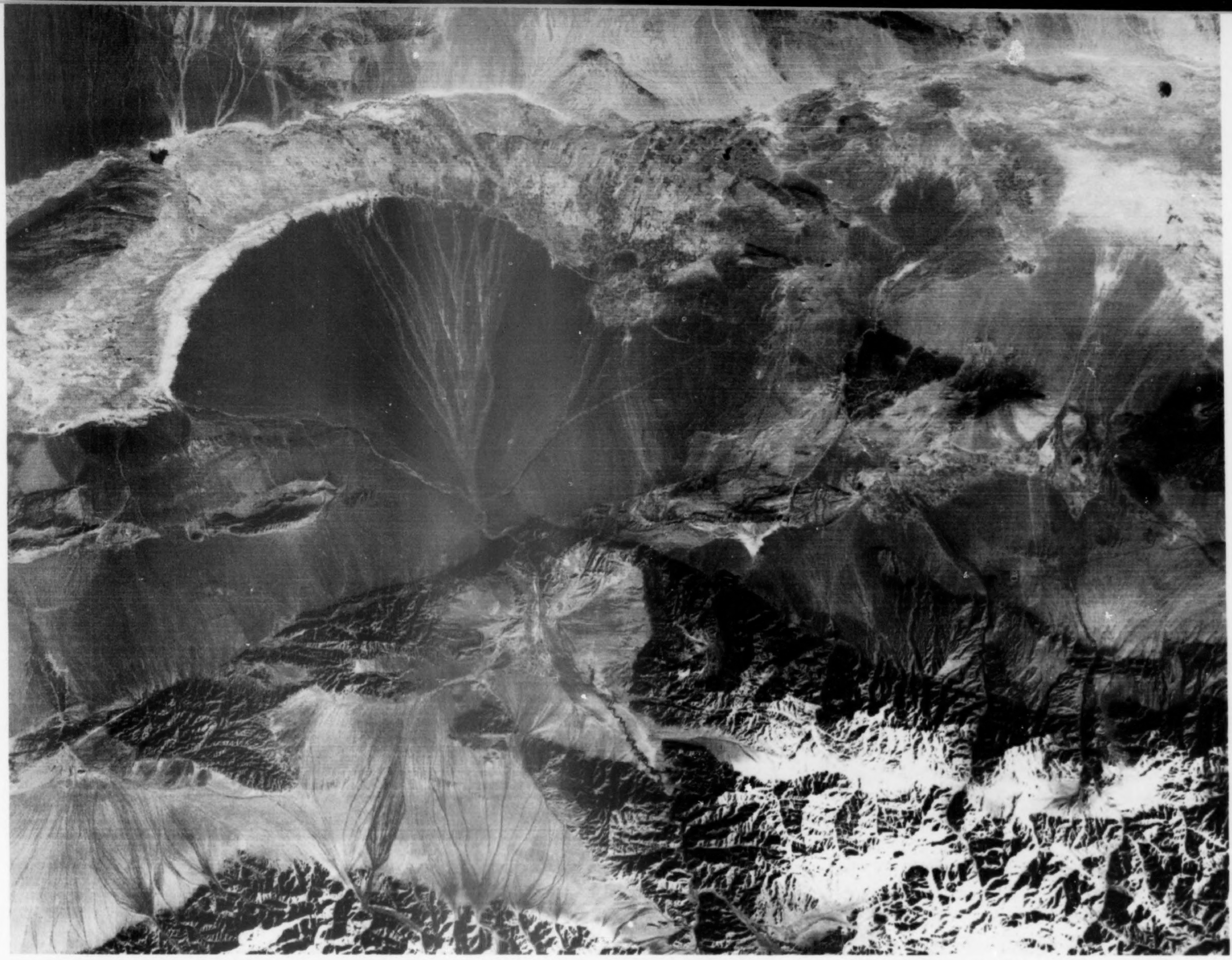
The Large Format Camera is presently scheduled to fly on Shuttle mission 16 in 1984 at an altitude of 300 km. From this altitude the camera will provide ground resolution of about 15 m/lp, which is an improvement over the European camera but is still inadequate. The stereoscopic coverage would permit compilation of contours at 25 m intervals.

To provide resolution required for compilation of cultural detail, NASA is considering adding two panoramic cameras that were made for the Apollo lunar program. In these cameras, the lens rotates about a horizontal axis and the film moves in the opposite direction during the exposure. The lens has a focal length of 61 cm and from the 300 km altitude would obtain ground resolution of about 3 m/lp. Two cameras would be used, one pointing forward and one pointing aft to provide suitable stereoscopic coverage. However, because of the moving parts, the panoramic camera lacks geometric integrity. The plan therefore, is to use the LFC with its attitude reference system and the Global Positioning System to establish a network of control points. These would meet the geometric requirements for 1:25,000-scale mapping and a 25 m contour interval anywhere in the world. The image detail from the very high resolution panoramic photographs would be adjusted to fit these control points. The resolution would be sufficient for reproduction as an image map at 1:25,000 scale and would also be adequate for compilation of cultural detail at that scale. The proposed array of cameras would be mounted on a rack for installation in the cargo bay of the Shuttle. Although all of the elements of this package have not yet been approved, it would provide the first opportunity for civilian mappers to compile both image maps and line maps at the most useful scales from space data.

Photogrammetrists and cartographers have waited a long time for a space system that would meet their requirements for standard mapping at useful scales. The technological means are at hand. What is needed now is the will to proceed and the development of the international institutional arrangements, which will bring this capability to the service of mankind. ■



The cartographic system being considered for the Shuttle will consist of the Large Format Camera (above) with a Stellar Attitude Reference Package to provide precise position and elevation data. Two panoramic cameras to provide high resolution stereoscopic photographs are also being considered.



Landsat image of the northern part of the Qaidam (Tsaidam) Basin in the Xinjiang (Sinkiang) Autonomous Region of northwestern China. The fan-shaped deposits (left-center) in the Hexi (Hosi) Corridor are formed by a river system that drains the Tibetan Plateau to the south.

(2675-03214; 27 Nov 76; Band 7; Courtesy EROS Data Center)

Dr. Farouk El-Baz, Director
Center for Earth and Planetary Studies, NASM

Landsat: An Eye in the Sky

The space program has allowed us to look at the Earth from a unique perspective. Photographs of the whole Earth that were taken by the Apollo astronauts from the vicinity of the Moon created new feelings and thoughts. These photographs vividly portrayed the Earth as a small, seemingly fragile planet silently floating in the vastness of space. They also revealed the beauty of our planet as a symphony of colors: the blue and green of oceans and seas, the vibrant white of clouds and ice, the brown and grey of mountainous areas, and the bright yellow and red of desert regions.

Mission after mission, it became increasingly obvious that photographs taken from space could tell us a great deal about the Earth, its landforms, and its natural resources. Today, we see an increasing emphasis throughout the world on the use of space photographs as a tool for resource development as well as environmental monitoring. This became particularly apparent with America's major Earth observation project: Landsat.

Almost ten years have passed since the launch of the first Landsat spacecraft on July 23, 1972. Since then, two other satellites from the same series were launched at three-year intervals, and a fourth is in preparation for launch in July 1982. Now after nearly 85,000 orbits around the globe and over one million images transmitted from space, Landsat has proved to be a very useful tool in studying the Earth's surface features.

Terrain study, however, was not the driving force in the selection of the particular sensors aboard Landsat. When NASA embarked on the design of the Earth Resources Technology Satellite (ERTS), as Landsat was called, there was much competition for first place among specialists in mapping and geology, ocean studies, and agriculture. The agricultural specialists required a method to inventory major crops. Their premse was that if space-age technology could provide a quick way to evaluate the wheat crops before the harvest, the data from this technology would have major marketing and political implications. The United States would be able to better predict market prices worldwide. With this argument, the agricultural team won, and a system was designed specifically to acquire data on crop inventories in a timely manner. Some accommodations were made, however, to satisfy the terrain mappers and the oceanographers.

The Landsat satellites are unmanned and operate from the relatively high altitude of approximately 920 km (570 mi.). Landsat spacecraft are in a near-polar orbit, therefore the polar regions are never covered by the images. The spacecraft orbit the Earth at an angle of 99° measured clockwise from the equator and complete a revolution in 103 minutes. Therefore, they fly over the same area of the Earth every 18 days. Each spacecraft is equipped with multispectral scanners that image selected portions of the Earth on each orbit. One Landsat image covers about 34,000 sq km (13,127 sq. mi.) of the Earth's surface.

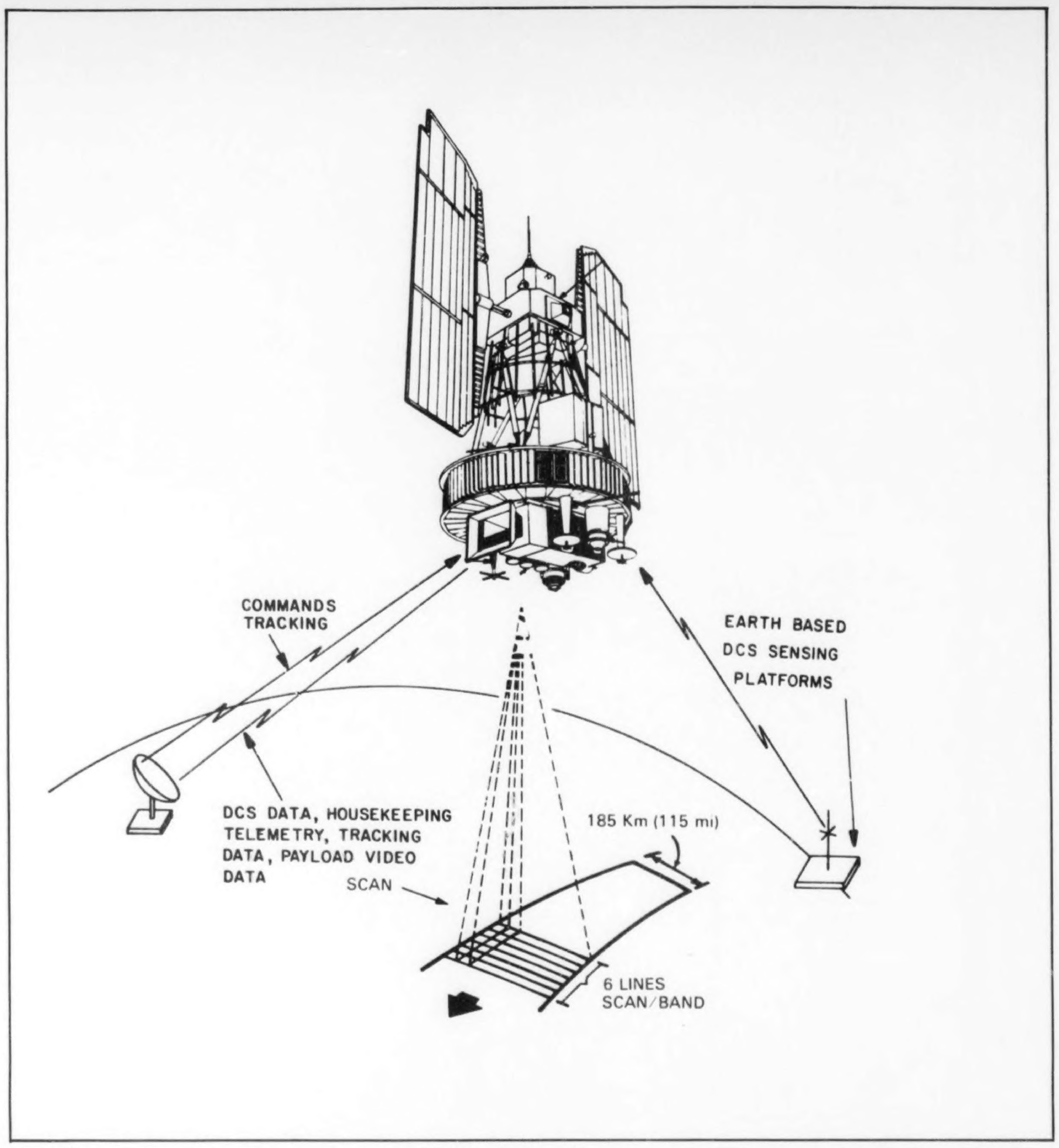
The multispectral scanners produce images representing four different bands of the electromagnetic spectrum. The four black-and-white bands are designated band 4 for the green spectral region (0.5 to 0.6 microns); band 5 for the red spectral region (0.6 to 0.7 microns); band 6 for a red to near-infrared region (0.7 to 0.8 microns); and band 7 for another near-infrared region (0.8 to 1.1 microns).

Light reflectance data from the four scanner channels for the four bands are converted first into electrical signals and then into digital form for transmission to receiving stations on Earth. The recorded digital video data are re-formatted into computer-compatible tapes and/or converted at special processing laboratories into black-and-white photo images. These images from the four different bands are recorded on four black-and-white films from which photographic prints are made in the usual manner.

Because each of the four bands records a different range of radiation, the black-and-white images provide different types of information. For example, the green band (band 4) most clearly shows underwater features and is therefore useful in coastal studies. The two near-infrared bands that measure the reflectance of the Sun's rays beyond the sensitivity of the human eye (visible range) are more useful in agricultural studies.

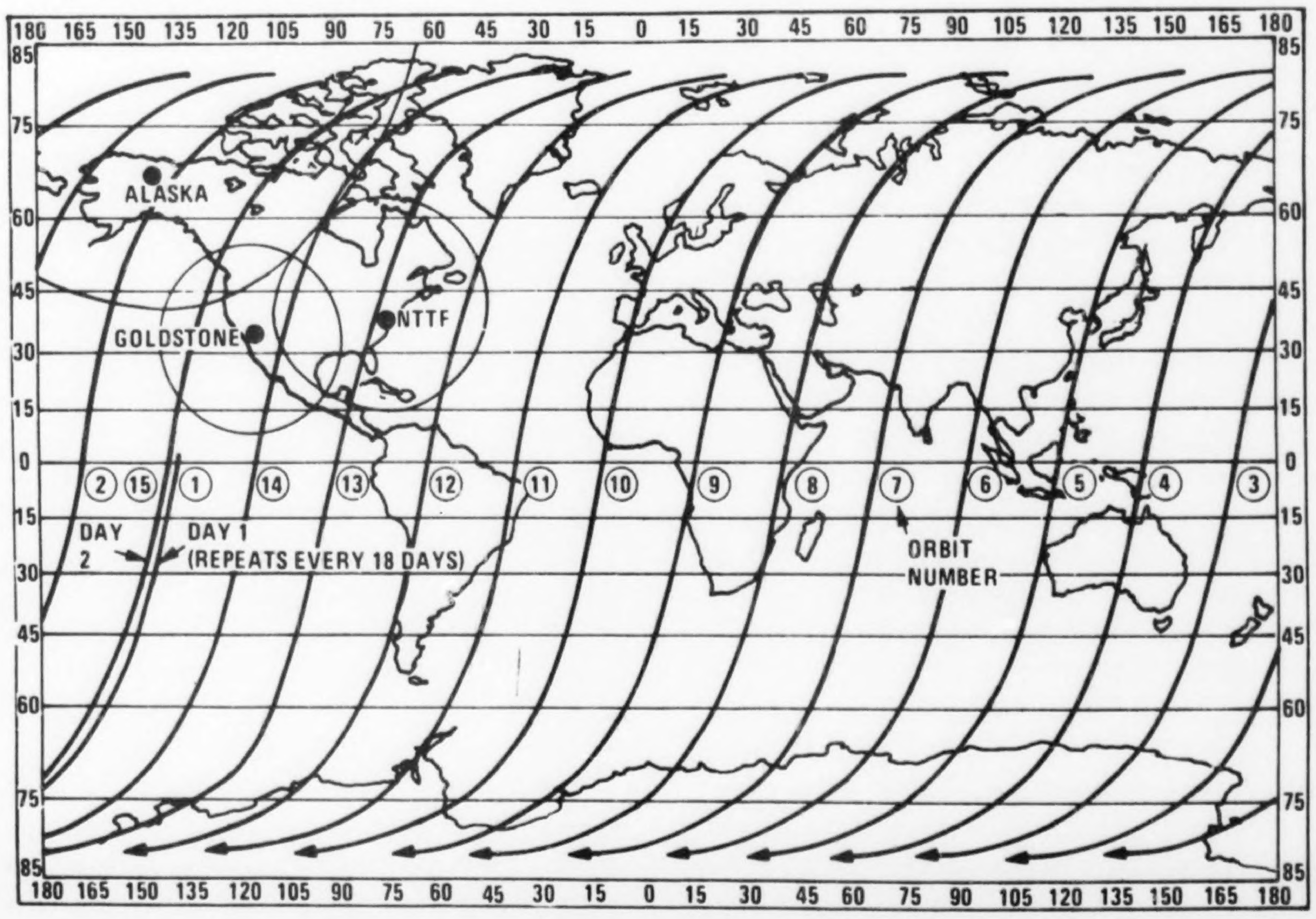
False-color images are produced when the bands are combined. In most cases, images are made by combining bands 4, 5, and 7. In this combination the red color is assigned to the near-infrared band number 7 making vegetation appear red. Because chlorophyll in plants is one of the most reflective materials, the healthier the vegetation, the redder the image. Also, because water absorbs the Sun's rays, clear water appears black on band 7 and on the false-color composite images as well.

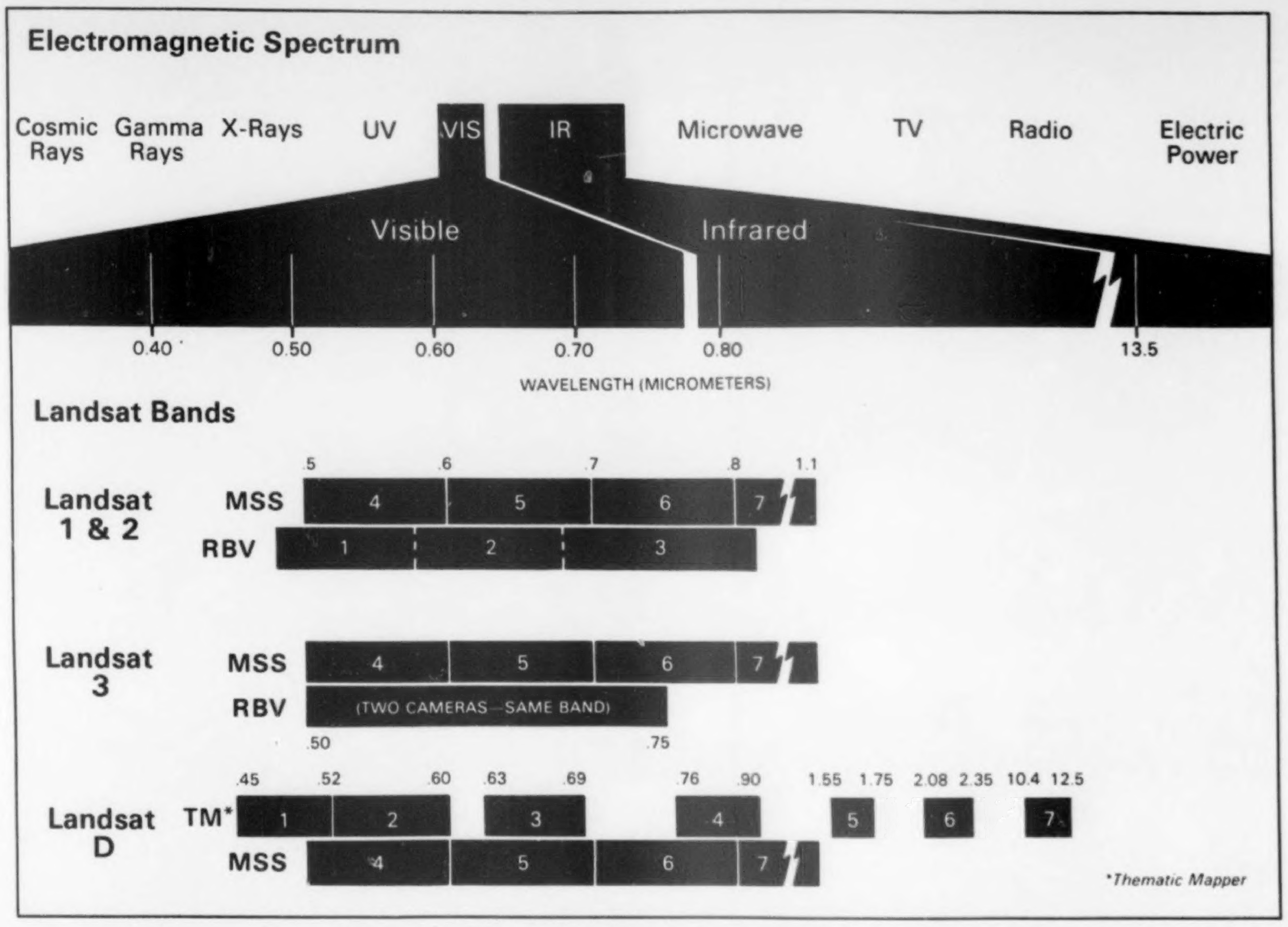
Thus, it is clear that the Landsat images have many useful characteristics, but their limitations must also be pointed out: (1) the low resolution of 80 m (260 ft.), which means that an object must be larger than that to be recognizable on the image; (2) the mono-


COMMANDS
TRACKING
EARTH BASED
DCS SENSING
PLATFORMS
DCS DATA, HOUSEKEEPING
TELEMETRY, TRACKING
DATA, PAYLOAD VIDEO
DATA
SCAN
185 Km (115 mi)
6 LINES
SCAN/BAND

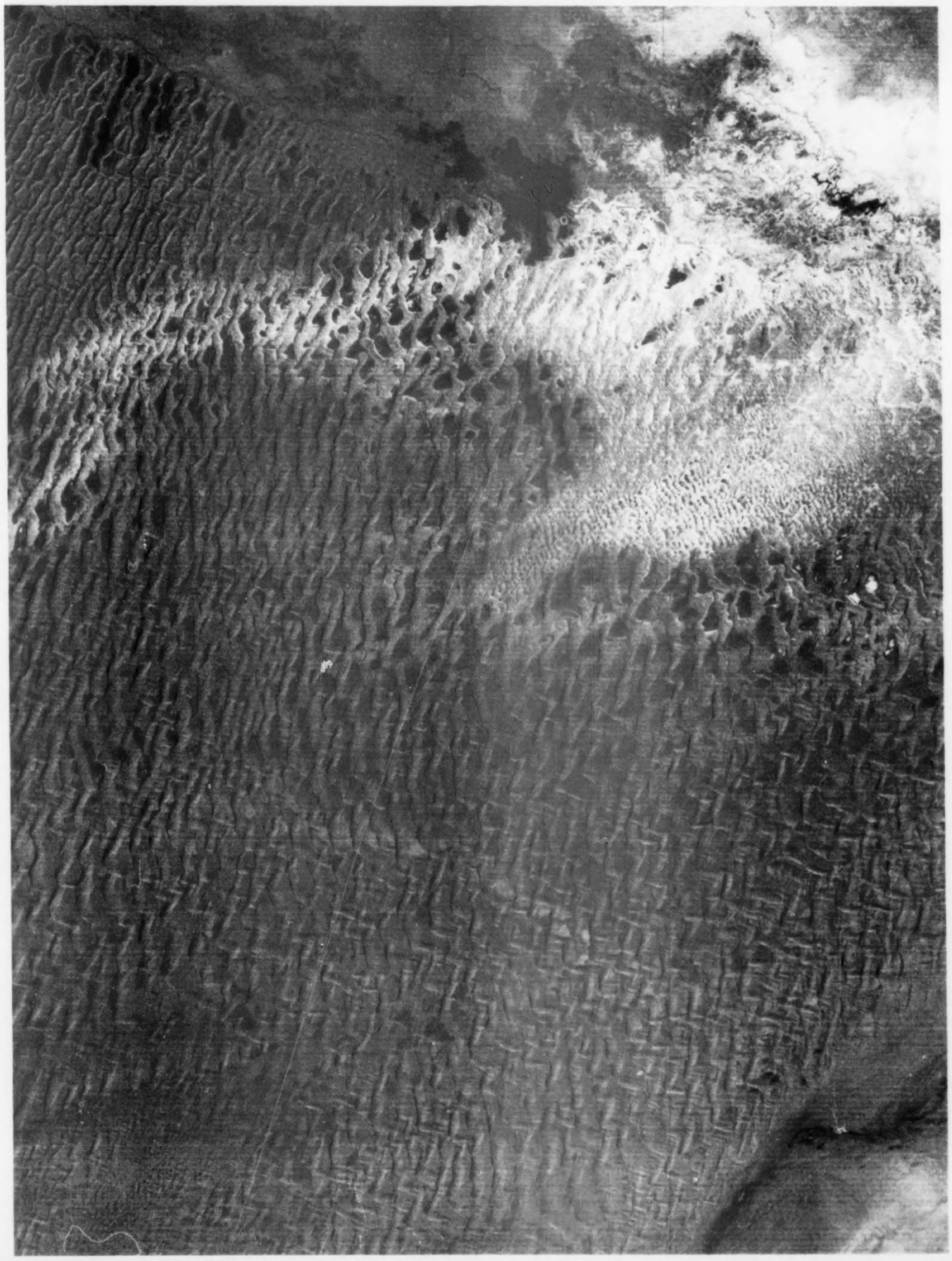
Earth-based data, such as temperature, stream flow, soil moisture, and snow depth, are supplied to the Data Collection System (DCS) on Landsat. Simultaneously, the Multi-Spectral Scanner (MSS) records an image that may be correlated with the Earth-based data later.

The Landsat satellite orbits the Earth in a near polar orbit every 103 minutes. It makes 14 orbits per day, crossing 0° latitude at 9:30 a.m. solar time each orbit. These daylight passes are superimposed on a world map illustrating the orbit of the satellite.


180 165 150 135 120 105 90 75 60 45 30 15 0 15 30 45 60 75 90 105 120 135 150 165 180
85
75
60
45
30
15
0
15
30
45
60
75
85
ALASKA
GOLDSTONE
NTTF
2
15
1
14
13
12
11
10
9
8
7
6
5
4
3
DAY 2
DAY 1 (REPEATS EVERY 18 DAYS)
ORBIT NUMBER


Electromagnetic Spectrum
Cosmic Rays
Gamma Rays
X-Rays
UV
VIS
IR
Microwave
TV
Radio
Electric Power
Visible
Infrared
0.40
0.50
0.60
0.70
0.80
13.5
WAVELENGTH (MICROMETERS)
Landsat Bands
.5
.6
.7
.8
1.1
Landsat 1 & 2
MSS
4
5
6
7
RBV
1
2
3
Landsat 3
MSS
4
5
6
7
RBV
(TWO CAMERAS—SAME BAND)
.50
.75
.45
.52
.60
.63
.69
.76
.90
1.55
1.75
2.08
2.35
10.4
12.5
Landsat D
TM*
1
2
3
4
5
6
7
MSS
4
5
6
7
*Thematic Mapper

Left: Bands on the Multispectral Scanner (MSS), Return-Beam Vidicon (RBV), and Thematic Mapper (TM) imaging systems are spatially compared to the enlarged visible and infrared sections of the electromagnetic spectrum.



Bottom left: Landsat image of desert dunes of the northeastern part of the Taklimakan Desert in the Tarim River Basin in the Xinjang (Sinkiang) Autonomous Region of northwestern China. The white area in the upper right represents a fine dusting of snow on the sand. The black areas nearby are water accumulations from snow melting.

(1128-04253; 28 Nov 72; Band 7; Courtesy EROS Data Center)

scopic coverage, which does not allow quantitative and systematic measurements of elevations and depressions in the Earth's topography (this means that Landsat data cannot be used to compile topographic maps); (3) the necessity for computer manipulation, which makes using the data relatively expensive; and (4) the fact that Landsat images do not portray natural Earth colors.

The Landsat data are indeed suitable for agricultural studies of large-area crop inventories. This is especially true in such vast, one-crop agricultural areas as the wheat belt in the United States. The repetitive coverage of the same region by Landsat satellites gives the researchers the required information on crop acreage and health in a timely manner. However, it was realized that Landsat data were not efficient in studying similar crops in other parts of the world, particularly where the size of the land plots is small or where many crops are raised within the same plots.

One of the least emphasized uses of Landsat images is in understanding geography. These images convey a vivid and lasting impression of the land, which supplements maps and other means of portrayal. The value of the Landsat images increases many times in areas that are poorly mapped. For example, Landsat images were used to study desert terrains where they were extremely useful in the establishment of sand dune distribution and in the selection of sites for detailed field investigations.

In spite of the success of the Landsat program and the many uses of its data, it was realized that its imaging system should be considered experimental. Further research and development have brought forth systems that are better suited for the detailed study of the Earth and its resources. Steps are now being taken by NASA to develop such systems on future missions to be launched by the Space Shuttle. ■

For further information about imagery of your hometown, contact: U.S. Geological Survey, EROS Data Center, Sioux Falls, SD 57198

The crew of the Stalinskiy marshrut—*Georgiy Baidukov, Valeriy Chkalov, and Alexander Belyakov—after the completion of their historic flight over the North Pole in June, 1937. Courtesy* Western's World *magazine.*

Von Hardesty
Associate Curator
Department of Aeronautics, NASM

The "Lindberghs of the North"

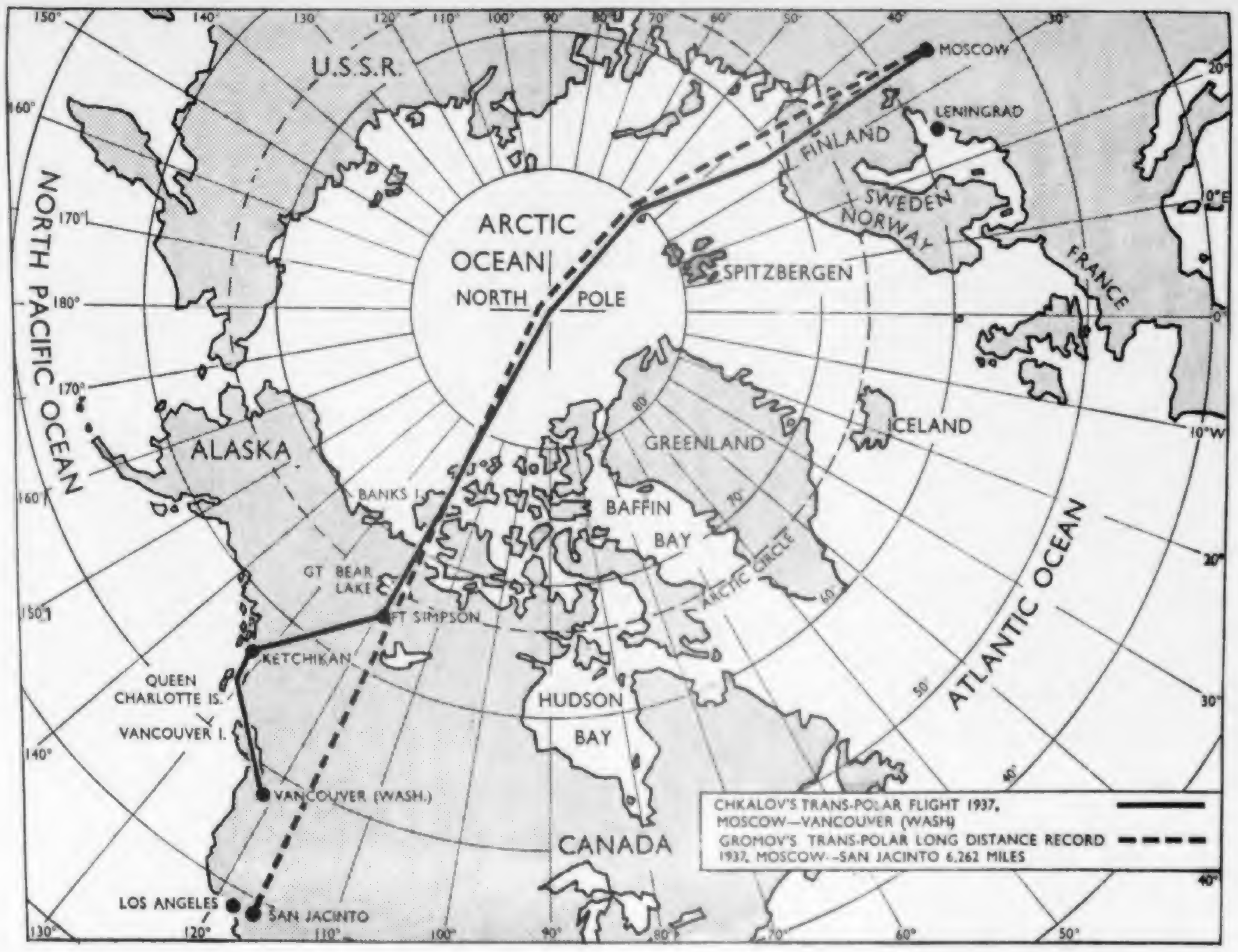
While many are familiar with Soviet achievements in space, few remember the first transpolar flight from Moscow to Portland, Oregon, in 1937. This epic flight by pilot Valeriy Chkalov, co-pilot Georgiy Baidukov, and radio-operator/navigator Alexander Belyakov captured worldwide attention at that time. For endurance and heroism, the flight of the Russian crew in the ANT-25 aircraft—the *Stalinskiy marshrut* (Stalin route)—rivaled Lindbergh's transatlantic crossing. As with Sputnik 20 years later, the transpolar flight of Chkalov and crew showcased Soviet technological advances.

Fliers such as Chkalov, Baidukov, and Belyakov occupied prominent places in Soviet public life in the 1930s, not unlike the status of cosmonauts a generation later. In 1936, the Soviet crew had flown a 9334 km (5800 mi.) path over the Siberian Arctic, passing over a vast stretch of Russia's Arctic coastline to the North Pacific. During this flight, Chkalov skillfully landed his ANT-25 at Udd (now Chkalov) Island in complete darkness. With this dress rehearsal completed, Chkalov appealed to Stalin for permission to make a transpolar flight to the United States. Stalin told his "falcons" that they could attempt the dangerous flight, but if conditions proved difficult over North America they were to land in Canada, and if any real emergency arose they were to land immediately. Always alert to propaganda considerations, Stalin demanded that this long polar flight not end in disaster.

Their single-engined ANT-25, designed by A.N. Tupolev, had special characteristics for long-distance, cold weather flying. The *Stalinskiy marshrut* was an all metal, low-wing monoplane with exceptional durability. While slow and awkward in appearance, the aircraft excelled in the critical categories of reliability and range. The liquid-cooled AM-34R V-12 engine rated 950 hp with its fixed pitch, three-bladed propeller. With its enormous wingspan 34 m (112 ft.), small fuselage, and relatively low power, the ANT-25 performed like a powered-glider. Its wings were covered with varnish-impregnated fabric to reduce drag, and integrated wing tanks enhanced fuel capacity to nearly 7570 L (2000 gal.).

On the morning of June 18, 1937, the *Stalinskiy marshrut,* looking in silhouette like a pterodactyl, took off on a specially constructed "hill" at the end of a paved runway near Moscow. Once airborne, Chkalov set the heading for the North Pole. When the lake and swamp country northeast of Leningrad gave way to the Arctic Basin, the crew began to sense their solitude. The brilliant Sun above and the icy wasteland below combined to create a mood of profound isolation. Only the sound of the aircraft's engine broke the silence.

Navigation over the North Pole required special equipment and techniques. Near the Earth's magnetic poles, the lines of force become almost vertical, and there is nothing for a compass to measure. Consequently, the ANT-25 was designed with a bubble canopy for a Sun compass and a special hatch for the navigator's sextant. Celestial navigation was the sole means for the Soviet crew to plot their course. During the time of the 1937 flight the Sun hovered above the polar horizon for more than 45 hours, giving the *Stalinskiy marshrut* a point of reference over the snowy landscape. Once over the North Pole, navigator Belyakov followed a planned


U.S.S.R.
NORTH PACIFIC OCEAN
ARCTIC OCEAN
NORTH POLE
MOSCOW
LENINGRAD
FINLAND
SWEDEN
NORWAY
FRANCE
SPITZBERGEN
ICELAND
GREENLAND
ALASKA
BANKS I.
BAFFIN BAY
ARCTIC CIRCLE
ATLANTIC OCEAN
GT BEAR LAKE
FT SIMPSON
KETCHIKAN
QUEEN CHARLOTTE IS.
VANCOUVER I.
HUDSON BAY
VANCOUVER (WASH.)
CANADA
LOS ANGELES
SAN JACINTO
CHKALOV'S TRANS-POLAR FLIGHT 1937, MOSCOW—VANCOUVER (WASH)
GROMOV'S TRANS-POLAR LONG DISTANCE RECORD 1937, MOSCOW—SAN JACINTO 6,262 MILES
150°
140°
130
120°
110°
100°
90°
80°
70°
60°
50°
40°
30°
20°
10°E
0°
10°W
160°
170°
180°

Above: The Soviets made two historic transpolar flights in 1937. Pilot Chkalov, co-pilot Baidukov, and radio-operator/navigator Belyakov captured worldwide attention at that time, flying from Moscow to Vancouver (near Portland, Oregon). Later that year, Commander Gromov, A. Yumasheff, and S. Danilin made a new transpolar long-distance record flying from Moscow to San Jacinto, California.

course on the 123rd meridian to America. A radio beacon was helpful only at the very end of the flight.

The black-nosed *Stalinskiy marshrut* with its enormous red wings moved slowly on its flight path at a mere 212 km/h (131 mph). For the nonstop flight of almost three days, the crew observed a strict regimen of eight hours on duty, followed by eight hours of sleep. The routine was not only tedious, it was cold. Even with a cabin heater, the temperature inside the aircraft hovered around -6°C for most of the journey. The outside temperature dipped to -24°C during phases of the long trek.

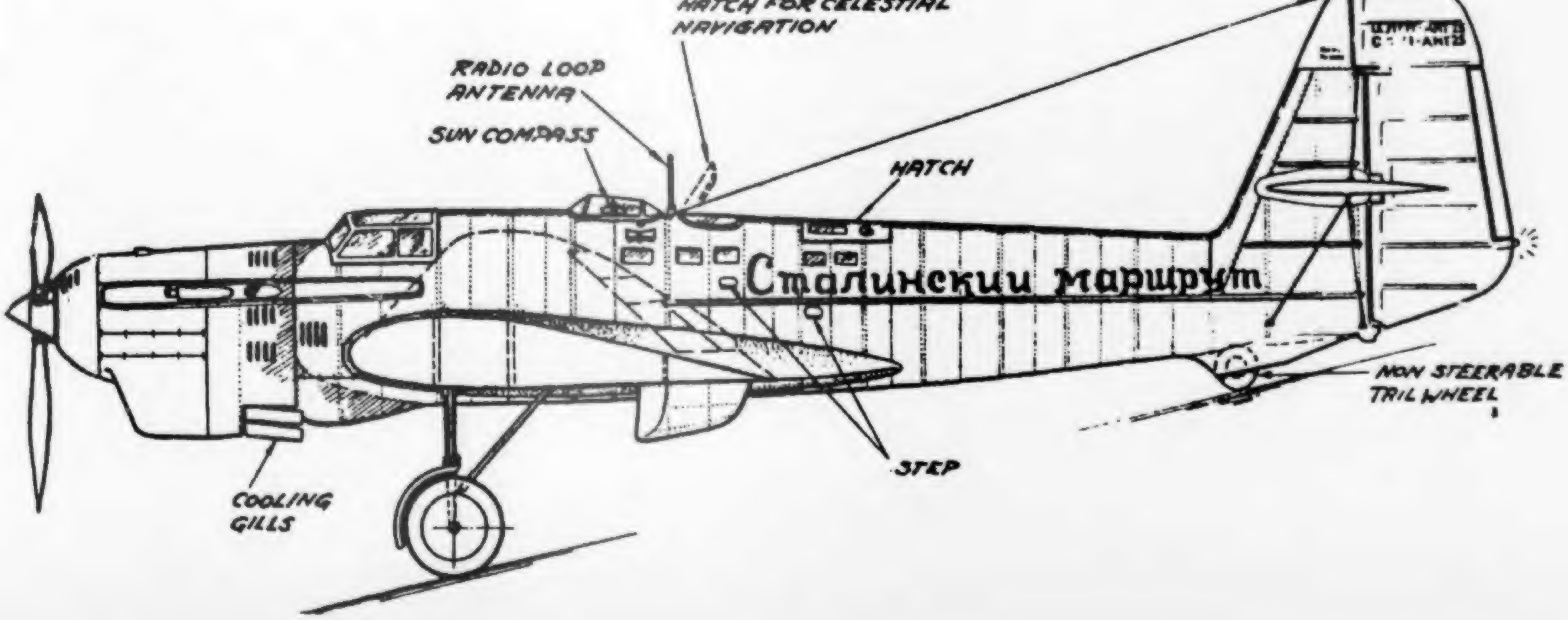
The Soviet fliers faced many dangers in the first hours of their flight. Ice formations appeared on the cowling and wings ten hours out, when Baidukov, at the controls, flew into a huge cloud formation near the Kola Peninsula. Fearing loss of control, Baidukov began a gradual ascent. At 2499 m (8200 ft.), the aircraft pierced the top layer of the clouds, and the crew began to relax as the Sun burned away the ice on the windows and wings.

At 27 hours the Soviet fliers crossed the North Pole at an altitude of 4145 m (13,600 ft.). The passage to the top of the Earth brought new anxieties. The precious oxygen supply was limited and the crew, forced to fly at high altitudes for long stretches, had used more oxygen than anticipated. Each successive layer of clouds had compelled the aircraft to climb, eventually reaching 57,000 m (18,700 ft.).

When Chkalov and crew reached Cape Perry, Canada, the *Stalinskiy marshrut* had descended to a cruise altitude of 3048 m (10,000 ft.) in clear air. At this point, they had flown more than 6115 km (3800 mi.). They looked down to see Great Bear Lake frozen solid and the barren tundra stretching to the horizon. Chkalov throttled back the dependable ANT-25 engine to 1480 rpm to conserve fuel. Adding to their growing confidence, the Mackenzie River appeared below them as anticipated.

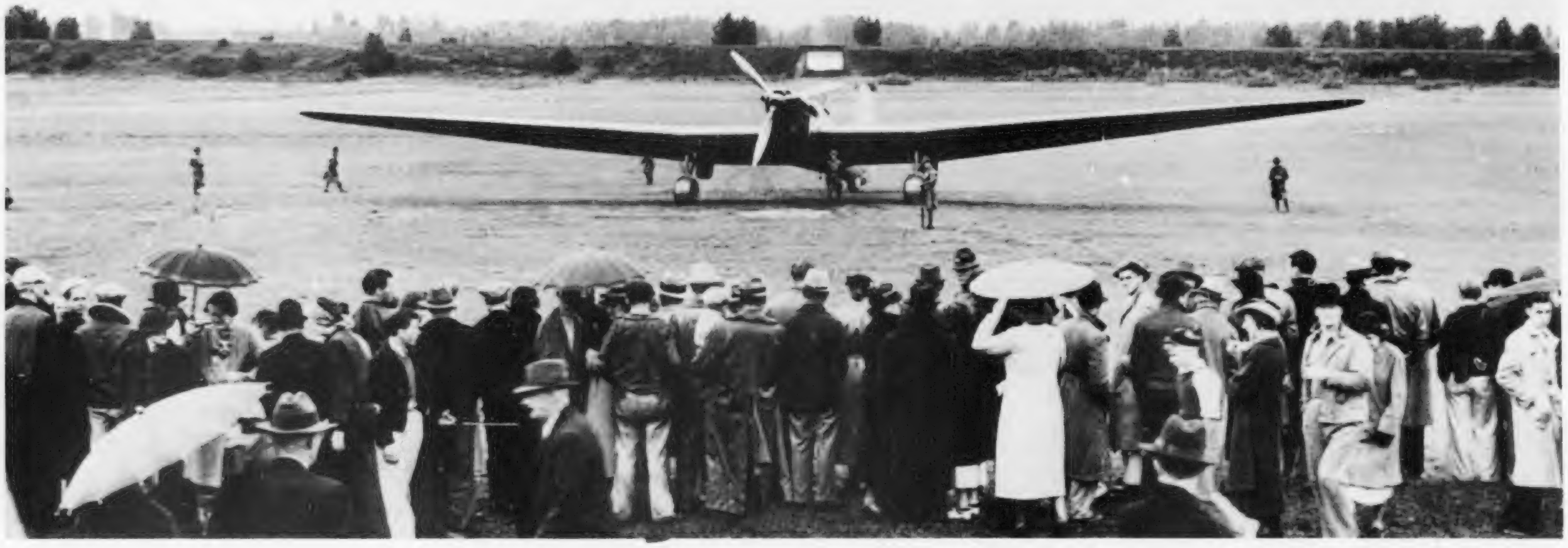
The mood of optimism changed abruptly as the *Stalinskiy marshrut* approached the Mackenzie Mountains (3048 m—10,000 ft.), which stood across their path as a cloud-shrouded barrier. To the east, storm clouds were building, and Baidukov altered the course slightly, ascending to 3962 m (13,000 ft.). There was enough fuel for another 20 hours, but the threatening weather forced a quick decision: were the conditions so difficult that Stalin's instructions to land should apply?

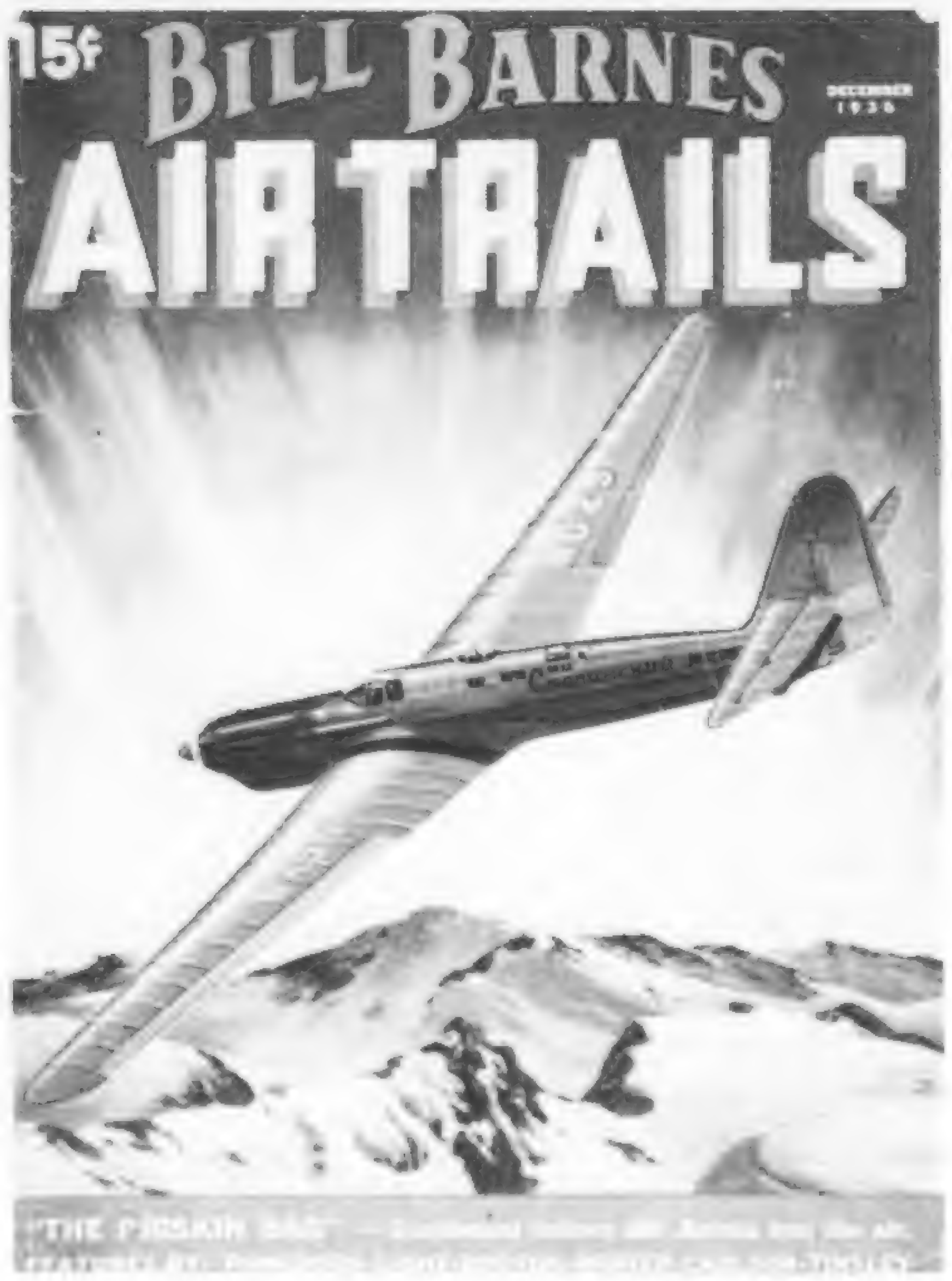
Rather than risk the uncertain fate of flying south into the interior of Canada, the Soviet fliers steered the aircraft


HATCH FOR CELESTIAL NAVIGATION
RADIO LOOP ANTENNA
SUN COMPASS
HATCH
Сталинскии маршрут
NON STEERABLE TRIL WHEEL
STEP
COOLING GILLS

Below: Detailed sketch of the single-engined ANT-25, Stalinskiy marshrut *(Stalin route), showing sun compass canopy and hatch for celestial navigation. A.N. Tupolev designed this aircraft for long-distance, cold weather flying. The all-metal, low wing monoplane had exceptional durability and range. The black-nosed* Stalinskiy marshrut *with its enormous red wings (34 m-112 ft.) performed like a powered glider.*

Adapted from Air Progress magazine; drawing by Bjorn Karlstom





Above: The single-engined ANT-25, looking like a giant pterodactyl with its enormous red wings, is parked at the U.S. Army airfield near Portland, Oregon, shortly after its historic flight over the North Pole. While slow and awkward in appearance—with the huge wingspan, small fuselage, and relatively low power—the ANT-25 performed well enough to set long-distance records.

Left: The epic flight of the ANT-25-1 Stalinskiy marshrut *(Stalin route) prompted considerable public interest.* Bill Barnes Air Trails *featured the aircraft on the cover of its December 1936 issue.*

Below: Comdr. Mikhail Gromov, Andrei Yumasheff, and Sergei Danilin established a new long-distance record of 10,077 km (6262 mi.) in the ANT-25-1. They flew from Moscow, over the North Pole to a cow pasture near San Jacinto, California, in July 1936.

west across the Rocky Mountains. They hoped to reach the open sea by nightfall. To safely cross the Rockies, Baidukov climbed to 5486 m (18,000 ft.), a move that drew again on the diminishing supply of oxygen. They had been in the air now for 46 hours. Chkalov and Baidukov, alternating at the controls, showed acute signs of fatigue and anoxia.

The crisis worsened when Baidukov, nearly exhausted, flew cautiously into a high bank of clouds at 5791 m (19,000 ft.). Upon entering this murky domain, the ANT-25 became more difficult to control as the wind turbulence buffeted it. As this challenge occupied Baidukov's waning strength, Belyakov announced that the oxygen supply was nearly gone. Descent toward the unseen terrain below now became mandatory.

For an hour Baidukov, on the edge of consciousness, guided the aircraft slowly toward lower altitudes. At 3962 m (13,000 ft.), they burst out of the envelope of fog into an open stretch between two cloud layers. Through the lower stratum of clouds, they caught sight of the sea. They had crossed the Rockies!

Belyakov quickly set the heading for Vancouver Island, about 885 km (550 mi.) southeast. As they flew toward the cloud-covered coastline, Chkalov radioed Anchorage, Alaska. This conversation was frustrating because Chkalov could not speak English and the Anchorage station could not understand Russian.

The final leg to Portland was flown in complete darkness and through a hailstorm. With the Columbia River as a reference point, Baidukov guided the *Stalinskiy marshrut* to a U.S. Army airfield near Portland on the morning of June 20, 1937. They had flown 8862 km (5507 mi.) in a nonstop 62½ hour flight. Although nearly forgotten, this remarkable flight represents an important chapter in the history of polar aviation. ■

Jay Spenser
Department of Aeronautics, NASM

Aerial Observation

Aerial observation has delighted mankind since the first flying machines were built. New views of the Earth, seen from above as a wondrously unfolding panorama, have satisfied an age-old dream. They have also presented new challenges. The methods and goals of airborne observation have evolved as rapidly as the flying machine itself. Today we look at ourselves from space with a vast array of technological tools.

Although the poetic aspects of flight captured the imagination of early aeronauts, the potential of balloons as observation posts was soon appreciated. In 1793, ten years after the first manned ascent in the Montgolfier hot air balloon, France formed a military detachment of tethered balloons. In 1794, one of these successfully scouted enemy movements during the turmoil of the French Revolutionary Wars.

Napoleon reportedly sent balloon teams to Italy and Egypt late in the 18th century, but it was not until the 19th century that aerial reconnaissance truly proved its worth. A key technological element in this aerial reconnaissance development was photography, at that time a young science. The first aerial photograph was taken in 1858 by Gaspard Felix Tourchon. Russia also pioneered in this field and is generally credited with the first naval aerial reconnaissance. Russia's techniques were successfully employed in the 1904 Russo-Japanese War.

24 VOLTS
TURRET
PLUG

A U.S. Army Air Force photographer demonstrates the use of a Fairchild hand-held camera during World War II.

There were many experiments with balloon observation in the United States during the Civil War; among them were the efforts of John Wise and John Le Mountain. However, Thaddeus Lowe was by far the most important of the Civil War balloonists, providing valuable information to the Union forces in his more than 3,000 flights. Lowe learned to make use of varying winds at different altitudes to drift over enemy lines and then return. Initially rebuffed by the U.S. government, Lowe turned to his friend Joseph Henry, first Secretary of the Smithsonian Institution, for help in presenting his ideas on balloon observation. Henry arranged a meeting with President Lincoln and accompanied the balloonist to the White House.

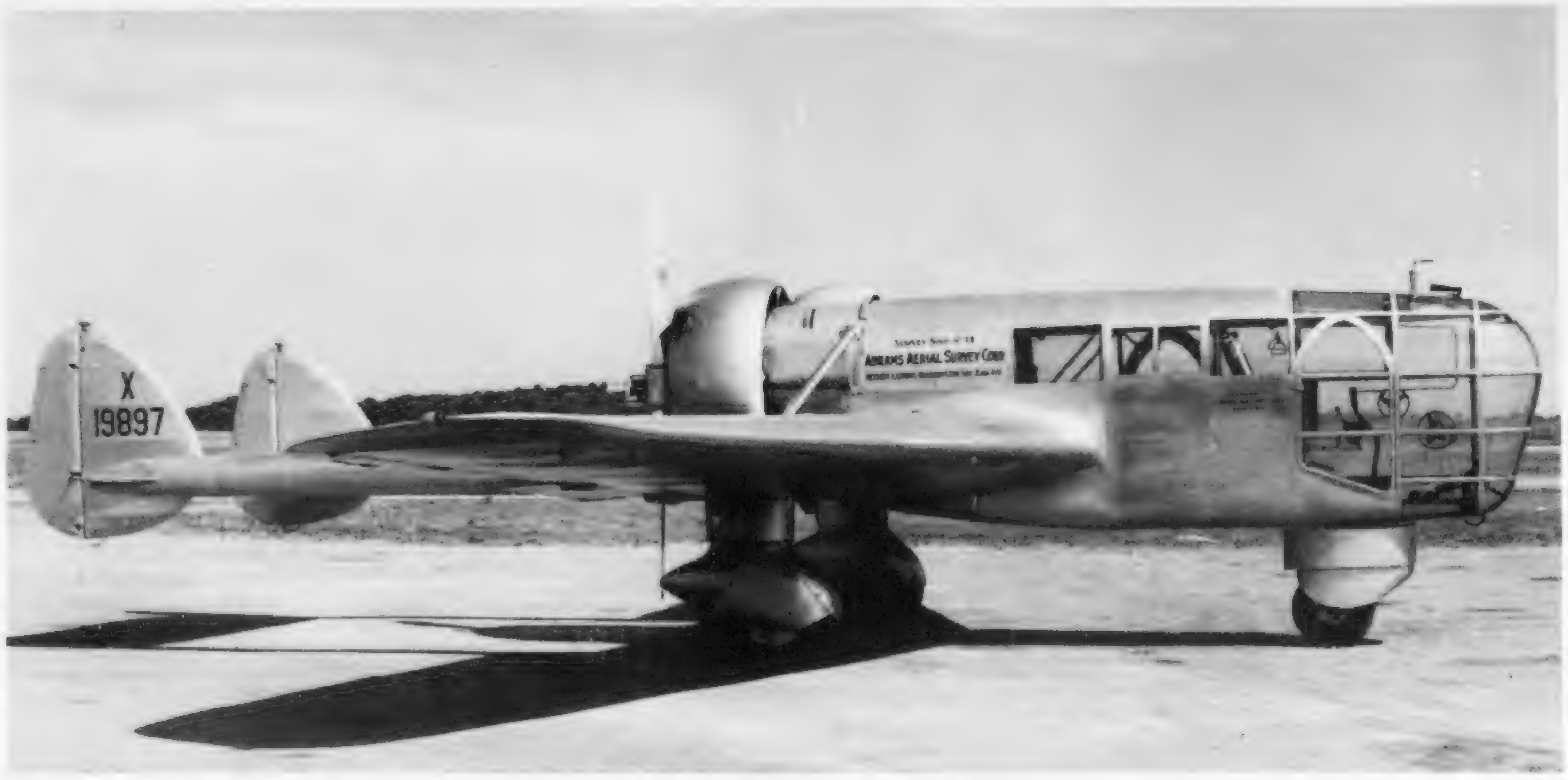
A demonstration was held on June 18, 1861, in which Lowe sent Lincoln a telegram describing troop dispositions around the capital directly from the basket of his balloon. This and other advancements in the art of aerial reconnaissance, including artillery spotting, were among the contributions made by Thaddeus Lowe, which set the pattern for American aerial observation in both World Wars I and II.

Balloons were also used in the Spanish-American War and World Wars I and II, although the invention of the airplane in 1903 foreshadowed the eventual decline in usefulness of lighter-than-air observation. Dirigibles could be steered and were also used for observation up through World War II, but they were cumbersome and vulnerable in comparison. The airplane opened up new possibilities for reconnaissance activities, because it could fly substantial distances to gather information and was not at the mercy of the wind for directional control.

Observation was critically important in World War I, and initially the airplane was used in this role. In Europe in 1915, unarmed observation planes often passed each other as they carried out their duties in opposite directions. The realization of the damage that such intelligence-gathering flights were causing led to the introduction of armament and the development of fighter aircraft to shoot down reconnaissance planes. The importance of their mission routinely led British crews to fly to what was almost certain death in their hopelessly outclassed B.E.2 two-seaters, while German Rumplers, Albatroses, and LVGs often fell prey to allied fighters. The major combatants also depended greatly upon tethered "sausage" balloons for information on troop movements.

Aerial photography was the single most important tool of World War I, and significant advancements were made in both materials and techniques. In the seven months that American forces participated in the war, using French DeRam and British "L"-type cameras, they took approximately 18,000 negatives from which over half a million prints were made.

After the war, George W. Goddard



The Abrams Explorer of 1937 was specifically designed in Lansing, Michigan, for aerial survey work and photography.

Aircraft such as this Fairchild FC-2 were used extensively for aerial mapping in the United States and Canada.

was responsible in the United States for many important advances in aerial photography. Among his developments in the Army's Engineering Division at McCook Field, Ohio, were night-photography techniques and in-flight film development so that the finished print could be transmitted by wire across the country in a remarkably short time.

On the civil side, Sherman Fairchild made great contributions in the development of aerial cameras. The inventor of a behind-the-lens shutter, he devised and manufactured a famous series of large, long-focal-length cameras that were of great value in World War II. Fairchild also perceived the need for an airplane well suited to the demands of photographic work. The result was the Fairchild FC-2, an extremely significant plane in aerial mapping and record flights.

When Lt. Col. Henry H. "Hap" Arnold led a flight of ten Martin B-10 bombers from Washington, D.C., to Alaska and back in 1934, George Goddard went along and photographed 52,000 sq km (20,000 sq. mi.) of Alaska from 4877 m (16,000 ft.). When Air Corps Capts. Orvil Anderson and A.W. Stevens reached 22,066 m (72,395 ft.) in the research balloon "Explorer II" a year later, they learned a great deal about high-altitude photography in the course of taking 15,000 pictures. From this altitude, the curvature of the Earth could be seen; aerial photography had reached new heights in more than just literal terms.

The increasing capabilities of aerial observation meant that, by the late 1930s, an effective tool was available to help man understand the world he lives in. Geological surveys, mapping, demographic studies, and many other aerial analyses were now possible. It was at this time that the Abrams Explorer was built.

Designed and constructed for Talbert Abrams, to the specialized requirements of his aerial survey company, the Explorer was a two-seat airplane of unusual configuration. The tandem cockpit was extensively glazed for photography, and camera ports were built into the floor behind the pilot's seat. In the interest of visibility, the engine was mounted at the rear of the fuselage, and the twin tail extended from booms built into the wing. Every effort was made to achieve stability, good altitude performance, and excellent visibility. The Explorer first flew in 1937 and was donated to the Smithsonian Institution after five years of aerial mapping.

World War II saw the development of airborne radar. In the European Theater of Operations especially, where bad weather was often a factor, pathfinder aircraft could pick out topographical features and locate targets through the clouds. These ghostly phosphorescent images on cathrode-ray tubes were indeed a new way to view the Earth from above.

As in World War I, it was photography that provided a most significant tool. High-flying Junkers Ju 86 reconnaissance planes gave Germany invaluable information in 1941 during the invasions of the Soviet Union. England already had excellent aerial photographs of Germany, due in part to the prewar exploits of Sidney Cotton who flew a Lockheed equipped with concealed cameras on frequent business trips. All countries taking part in the war made use of aerial photography, using fighters and bombers as well as aircraft specially built for the purpose.

While the techniques were the same, there was greater technological sophistication available during the Korean conflict. Among the valuable innovations was a new film emulsion developed by George Goddard that showed vegetation as red and all camouflage as green.

In the early 1950s, cameras were sent high into the thin reaches of the atmosphere as the accelerated development of rocketry was pursued. When Sputnik was launched into orbit by the Soviet Union in 1957, it ushered in the space age. Cameras with sophisticated units for scientific and military purposes that see visible light and other spectra were placed in orbit around the Earth. These and other sensing devices today allow Earthbound scientists to track weather patterns, pinpoint and study pollution, monitor ocean temperatures, and obtain a clearer picture of our planet Earth.

Satellites enable us to see farther into space as well, without the atmospheric distortion that hampers ground-based telescopes. It is when we turn our cameras on the Earth, however, that we see we have indeed come a long way since man first looked down from the basket of a drifting balloon. ■

William A. Good
Museum Specialist, Art
Exhibits and Presentations Division, NASM

Our Beautiful Earth

Our view of the Earth was limited for centuries to what we could see as we moved about its surface. With the advent of flight, a new world emerged. To document this new world, intrepid photographers went up in balloons as soon as they, and their rapidly improving cameras, could be accommodated. Soon after the first aerial photograph in 1858, cameras designed to take pictures automatically were sent aloft on balloons, kites, and even tied to pigeons. With the invention of the airplane in 1903, another Earth viewing platform was created; its reconnaissance gathering capabilities played a critical role in World War I.

This new aerial view of the Earth was awesome. Rivers seemed to be ribbons of light flickering in the sunlight; forests became green carpets; and mountains showed the rhythmic signs of the Earth's contortions.

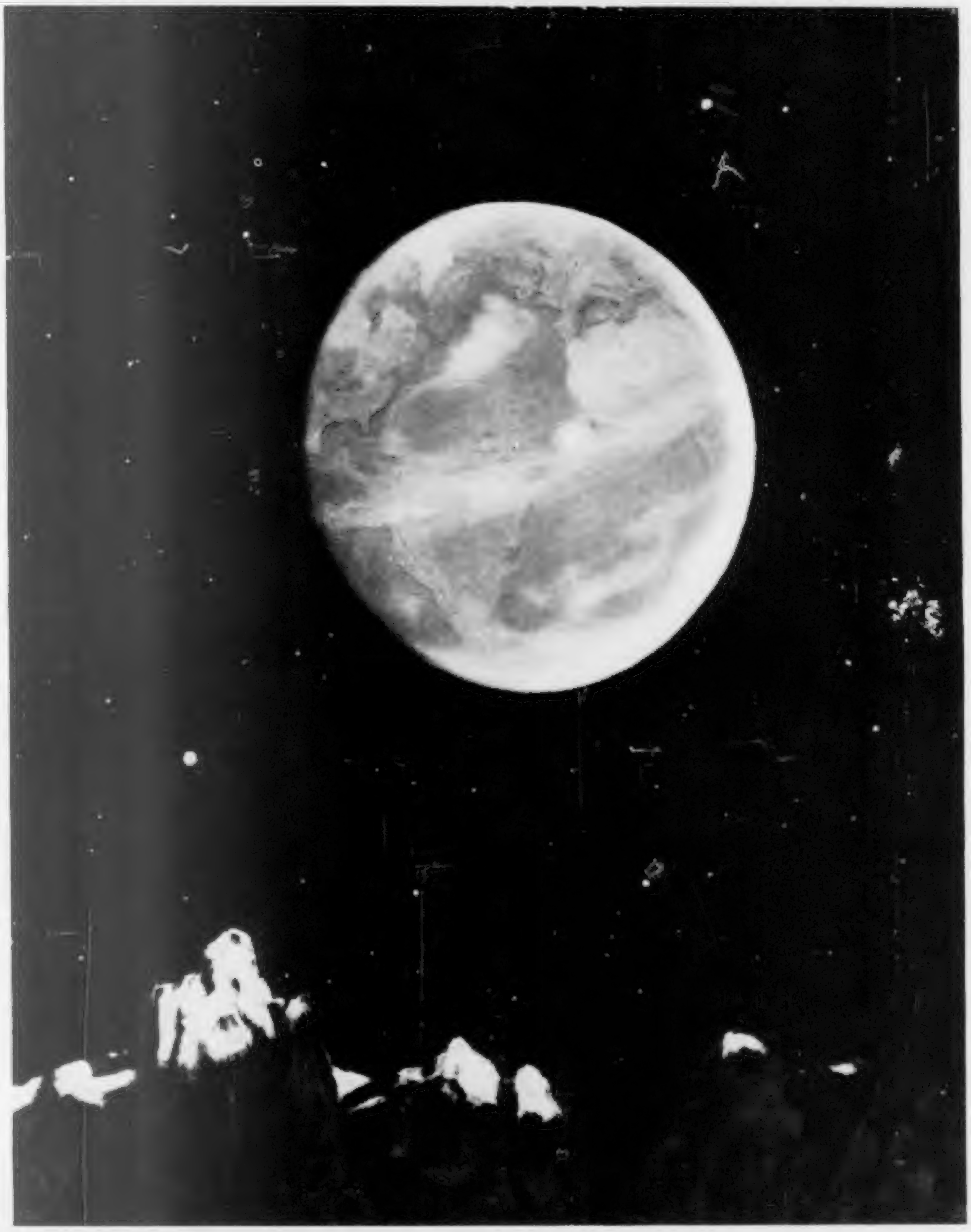
Painters also became involved with this new view of the Earth. Lt. Henri Farré, official painter to the French Army and Navy during World War I, reflected on his assignment:

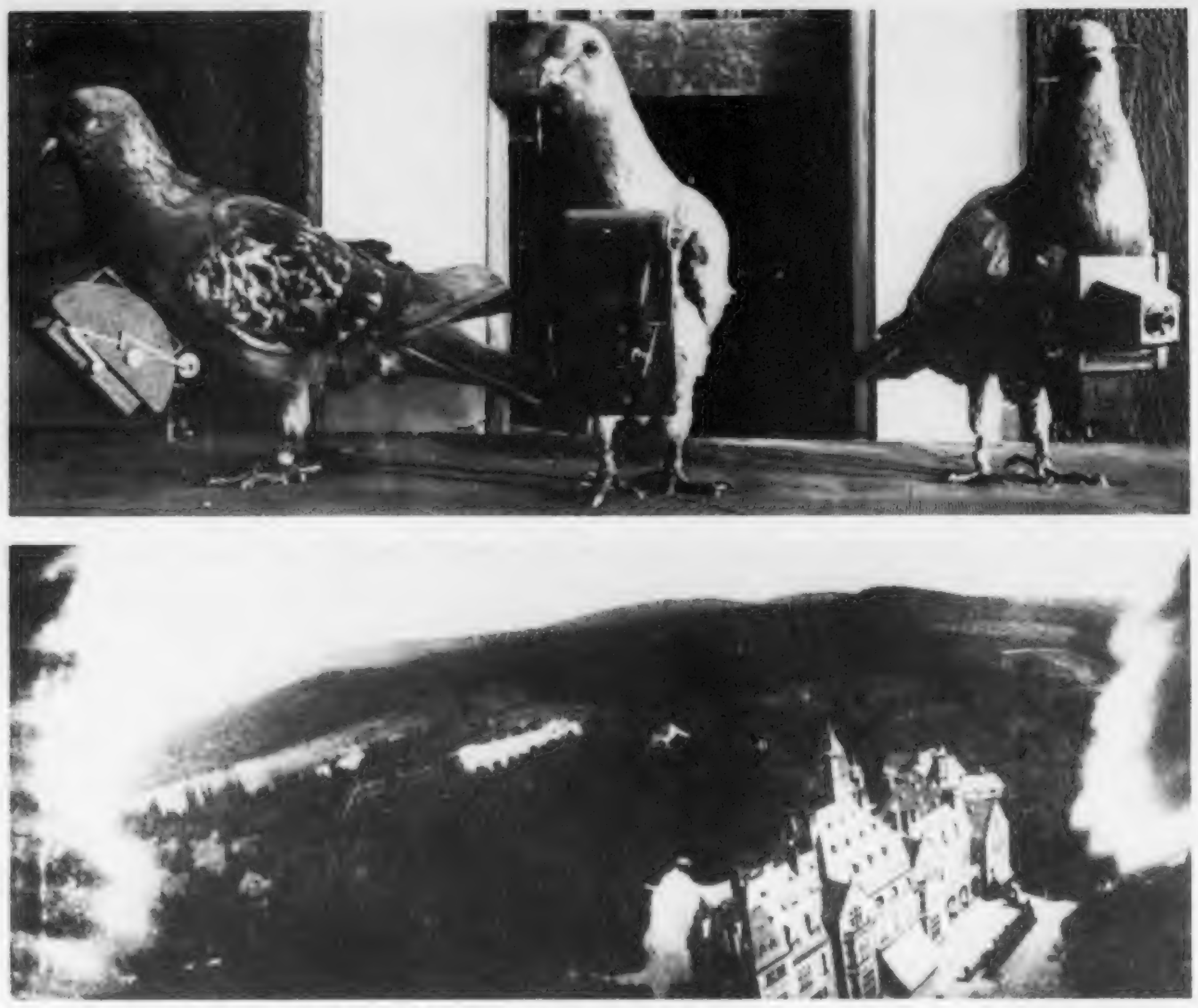
> It was, however, only after five months of constant flying that I was able to transform my way of seeing so as to paint things with an aerial vision, as it were. And in this transformation, it seems to me that a new art has been born, which I hope will be understood by terrestrial spectators.
>
> —Henri Farré
> "With the Sky Fighters of France," ca. 1918.

Earth views have fascinated visionary painters as well. Even before the technology of flight had advanced enough to reach desired vantage points,

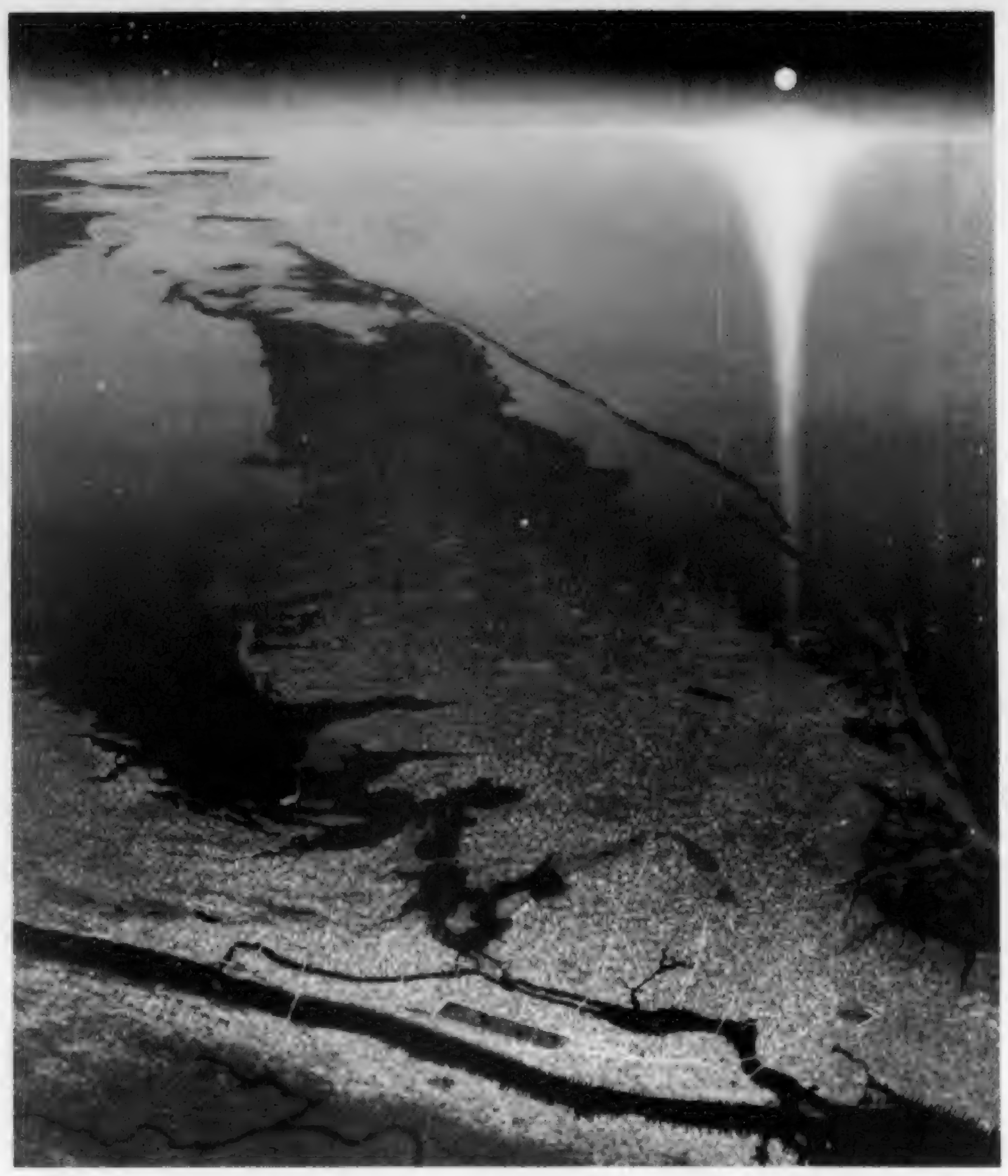
The Earth As Seen From the Moon
oil on canvas, 25" x 30"

Howard Russell Butler, ca. 1927





Pigeons produced aerial photos like this one taken of Germany in 1908 using 2½ oz. cameras with built-in timing devices. L'Illustration *magazine wrote: "It is quite natural to see birds becoming photographers at the moment when men are beginning to become birds."*
Courtesy Deutches Museum, Munchen



New York and Long Island From 25 Miles Up
oil, 23¼" x 19½" *© Chesley Bonestell 1949*

Sand Dune #3 *© William Garnett 1954*
Death Valley, Calif.

some imaginative artists got there their own way. Howard Russell Butler, who painted the Earth as a planet in space in the late 1920s, worked closely with astronomers to depict as much fact as possible. Chesley Bonestell also meticulously researches his paintings with the prevailing scientific thinking, as in his 1949 painting.

The present day artist-photographer flying close to the ground shows us that the aerial photograph offers more than simple facts. Seen from a distance, the Earthly sights that we take for granted assume a new beauty. Bill Garnett has earned his well-established reputation in the field flying for photographs since 1945. In 1956, he purchased a 1955 Cessna 170-B that he still uses for his work.

As the capabilities of flight have evolved, images of the Earth have been brought back from such programs as manned space flight and are continuously being sent back from unmanned satellites such as Landsat. These images, originally made for technical purposes, reveal that their beauty frequently outweighs their value as information. This new photographic resource has helped spawn a proliferation of Earth-looking artworks in recent years.

As the view of our Earth has changed through the aerial view, real and imagined, so have our lives changed. From geologists to agriculture experts to artists, the view has immensely expanded our vision. ■

Von Del Chamberlain
Astronomer
Department of Space Science and Exploration, NASM

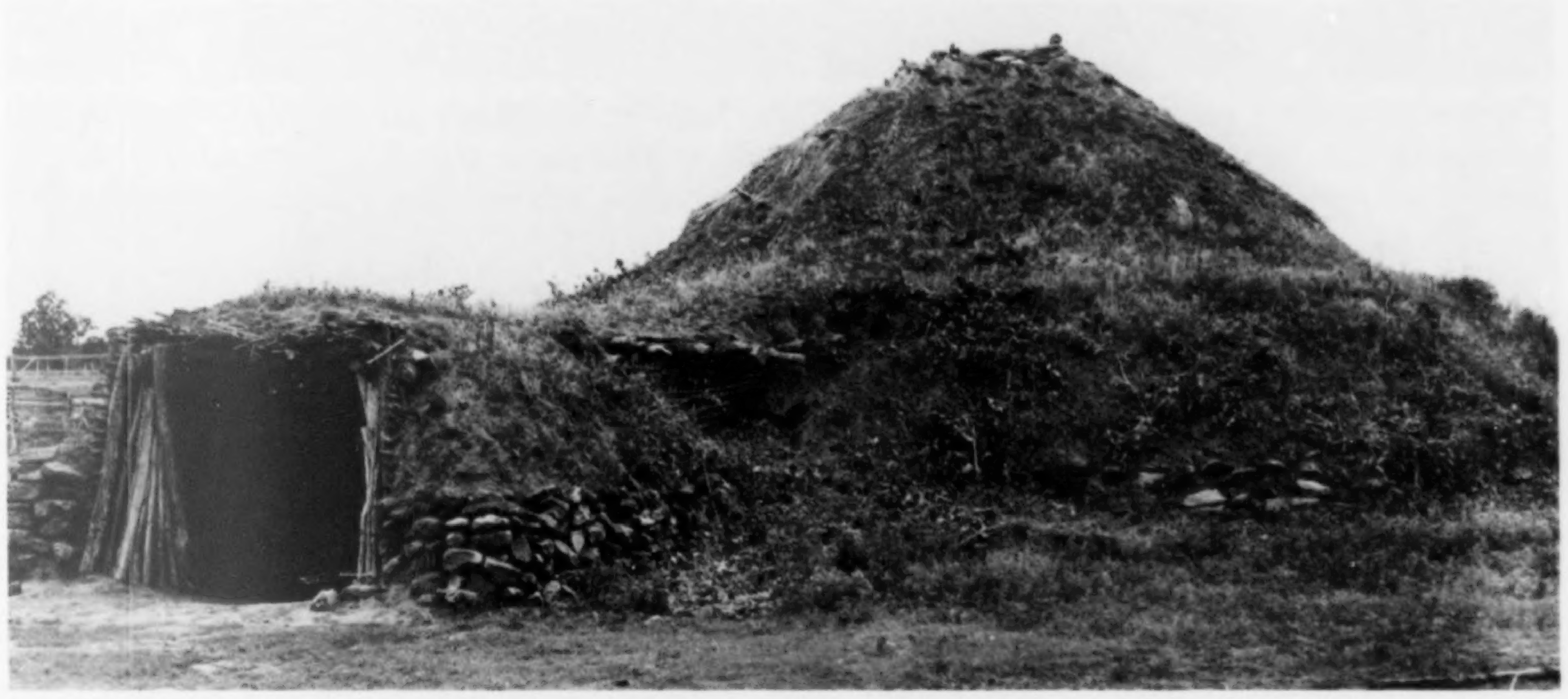
Observatories

From Sun Watching to Orbiting Telescopes

Almost all astronomy books begin by reminding the reader that people have always watched the objects of the sky and that astronomy is the oldest of the sciences. Since astronomy involves the study of untouchable objects, it depends upon observation. Observation is basic to survival, and humans are observers. We have both the ability and motivation to look around and to interpret what we see. We are, according to Greek philosopher Posidonius (135–51 B.C.), "Beholders and expounders of heaven." Our innate observational abilities have not changed much, but collectively our abilities to see more and to analyze what we see have improved immensely. The story of our ability to learn about stars is the story of observatories.

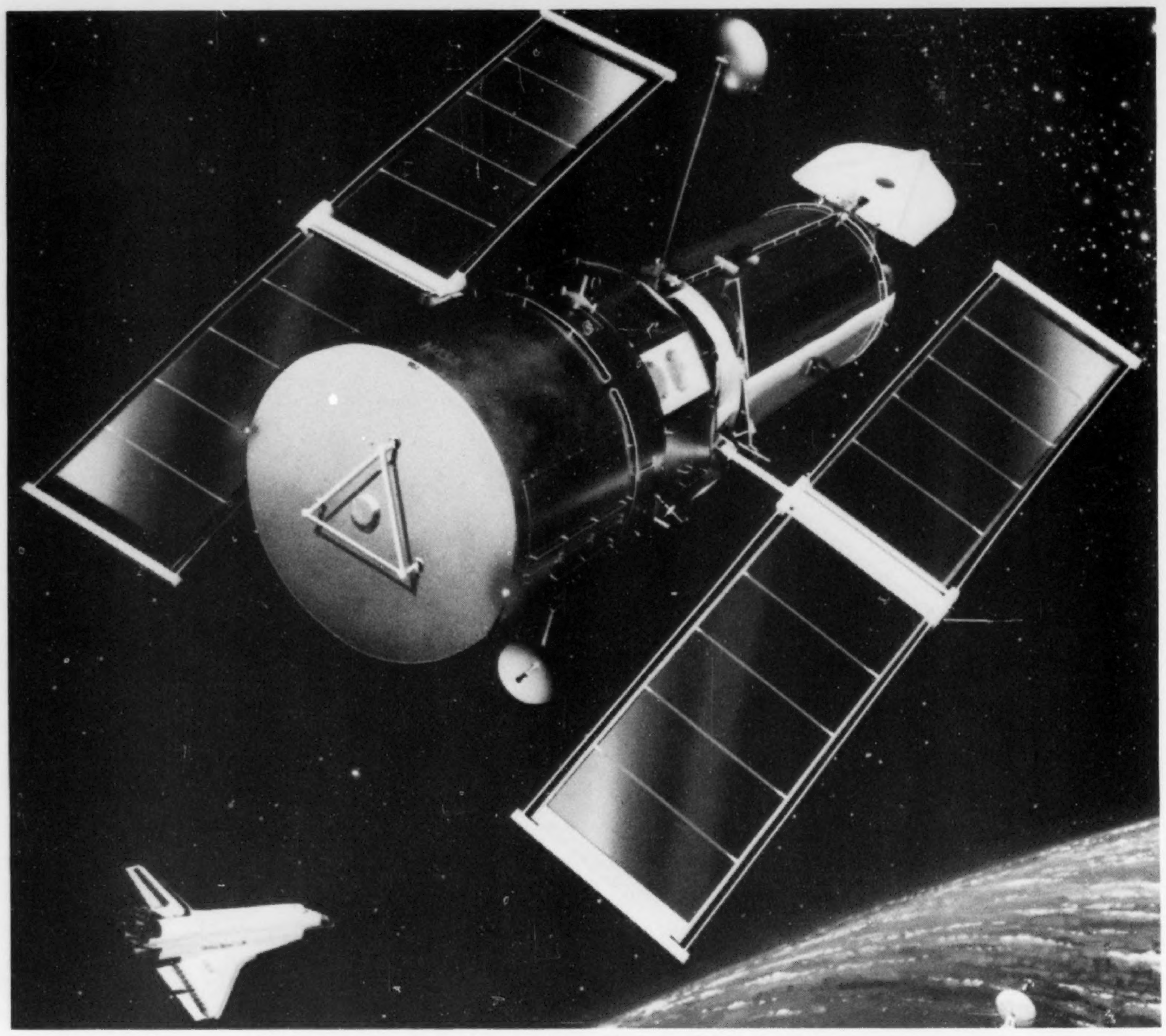
Observatory is defined as, "a building or station for the systematic observation of natural phenomena; especially, one for astronomical observation." Indeed, the first observatories were simply stations where people made observations of great importance to the group they represented. An example from the Zuni Indians illustrates the most primitive concept of an observatory:

> Each morning, too, just at dawn, the Sun Priest, followed by the Master Priest of the Bow, went along the eastern trail to the ruined city of Ma-Tsa-Ki, by the riverside, where, awaited at a distance by his companion, he slowly approached a square open tower and seated himself just inside upon a rude, ancient stone chair, and before a pillar sculptured with the face of the sun, the sacred hand, the morning star, and the new moon. There he awaited with prayer and sacred song the rising of the sun.
>
> —F.H. Cushing,
> *My Adventures in Zuni*, 1941.



The Earth lodge was both a home and an observatory for the Skidi Pawnee Indians. Skidi priests made observations through both the east-oriented entrance and the dome-shaped roof.
Courtesy of the American Museum of Natural History

Kitt Peak National Observatory Arizona. The world's best telescopes look out of domes on mountain tops to enable astronomers to continue learning everything possible about the stars.
Courtesy Von Del Chamberlain



The Space Telescope is planned to be launched by the Space Shuttle in the mid-80s and will give astronomers information about the stars that cannot be obtained from underneath the blanket of the Earth's atmosphere. The telescope will permit the observation of stars and galaxies 1/50th as bright as can now be observed by the largest ground-based telescopes.

The most important early observations were the directions of the rising and setting Sun. Astronomer-priests spent some time each day at Sun-watching shrines and became familiar with the annual swing of the Sun along the horizon. They memorized the features of the horizon and used them as markers on a calendar. Thus they knew that when the Sun rose or set at particular points on the horizon, as seen from the shrine, it was time for particular events: when to plant; when to expect or to perform rituals for rain; when to hunt; when to harvest the fruits, roots, and grains; and when to perform rituals of fertility and thanksgiving. These early skywatchers also noted clues from the movement of the stars and their relationships to the Sun. Using their observational knowledge, they developed methods of timing their activities to coincide with the behavior of other living things and climatic conditions on Earth.

The religious buildings and even the houses of some early peoples sometimes had the characteristics of an observatory. Small ports, or windows, often faced the sunrise or sunset at mid-winter and mid-summer. Marks were made on the walls opposite these ports, and on the proper days the first rays of morning light or last rays of daylight would fall upon the marks; this was an excellent way of keeping a simple calendar.

The Earth lodges of the Skidi band of Pawnee Indians, who lived in what is now east-central Nebraska, are examples of houses used as observatories. Such houses were large sod-covered dome-shaped structures supported by posts. There were two openings: a tunnel entrance opening to the east and a hole directly above the central fireplace. The Pawnees watched the play of sunlight through the tunnel entrance, and possibly through the smokehole, as a method of keeping their calendar of activities. They also observed the stars through both openings.

In some parts of the world where the Sun passes directly overhead at midday sometime during the year, zenith tubes were sometimes constructed. When sunlight passed directly down these long vertical shafts illuminating the floor without shadow, the observers knew that a specific day had arrived.

More elaborate observatories consisted of man-made alignments of features that marked the directions of the rising and setting Sun and other objects. Stonehenge in England is a well-known example. Others include the Big Horn Medicine Wheel in the mountains of Wyoming, and certain temples in Egypt, Greece, India, Mexico, and China. Some of these mark the directions of the mid-winter and mid-summer Sun. Some indicate the directions of rising of certain stars, and a few seem to mark the extremes of rising or setting of the Moon or even some planets, usually Venus. Some structures appear to have been erected so that the play of light and shadow could be used as a calendar device.

These traditional observatories satisfied the needs of early cultures and eventually led to our more modern observatories. First, sighting instruments, then telescopes were invented. As telescopes became larger and technology permitted more precise observations, special buildings were designed to position instruments permanently and effectively and to protect them from the weather. The first permanent optical observatory of major proportions was built at Greenwich, England, in the 17th century. Now in the United States we have the Mount Palomar Observatory with its 5-m (200-in.) telescope, the Mount Hopkins Observatory with the Multiple Mirror Telescope, the Kitt Peak National Observatory, which is sometimes referred to as "telescope national forest," and the National Radio Astronomy Observatory.

The greatest limitations of modern observatories are the effects of the atmosphere through which light must pass in order to reach the instruments. Moisture, dust, and temperature changes cause absorption, scattering, and bending of light, resulting in loss of precision. The best solution is to get telescopes above the atmosphere, which has been done for the past 20 years with orbiting astronomical observatories. Astronomers now look forward to the Space Telescope, which is under construction and planned for launch from the Space Shuttle.

Observatories are not new; they go back to the earliest human cultures. Our reasons for making observations, the equipment we use, the types of observations we make, and the range and quality of information we are able to obtain have changed greatly. Behind all of this are essentially the same basic human motives that started it all; first to survive—but also to understand our place in the things we see around us. ■

Suggested Readings

Aveni, Anthony F. 1980. *Skywatchers of Ancient Mexico.* Austin: University of Texas Press.

Chamberlain, Von Del. in press. *When Stars Came Down to Earth: Cosmology of the Skidi Pawnee Indians of North America:* Los Altos, Calif.: Ballena Press.

Cornell, James, 1981. *The First Stargazers.* New York: Charles Scribner's Sons.

Cushing, F.H. 1941. *My Adventures in Zuni.* Santa Fe: Peripatetic Press.

Eddy, John A. "Mystery of the Medicine Wheels." *National Geographic* 77:140–46.

Hanle, Paul A. and Chamberlain, Von Del, eds. 1981. *Space Science Comes of Age,* Washington, D.C.: Smithsonian Institution Press.

King, Henry C. 1979. *The History of the Telescope.* New York: Dover Publications.

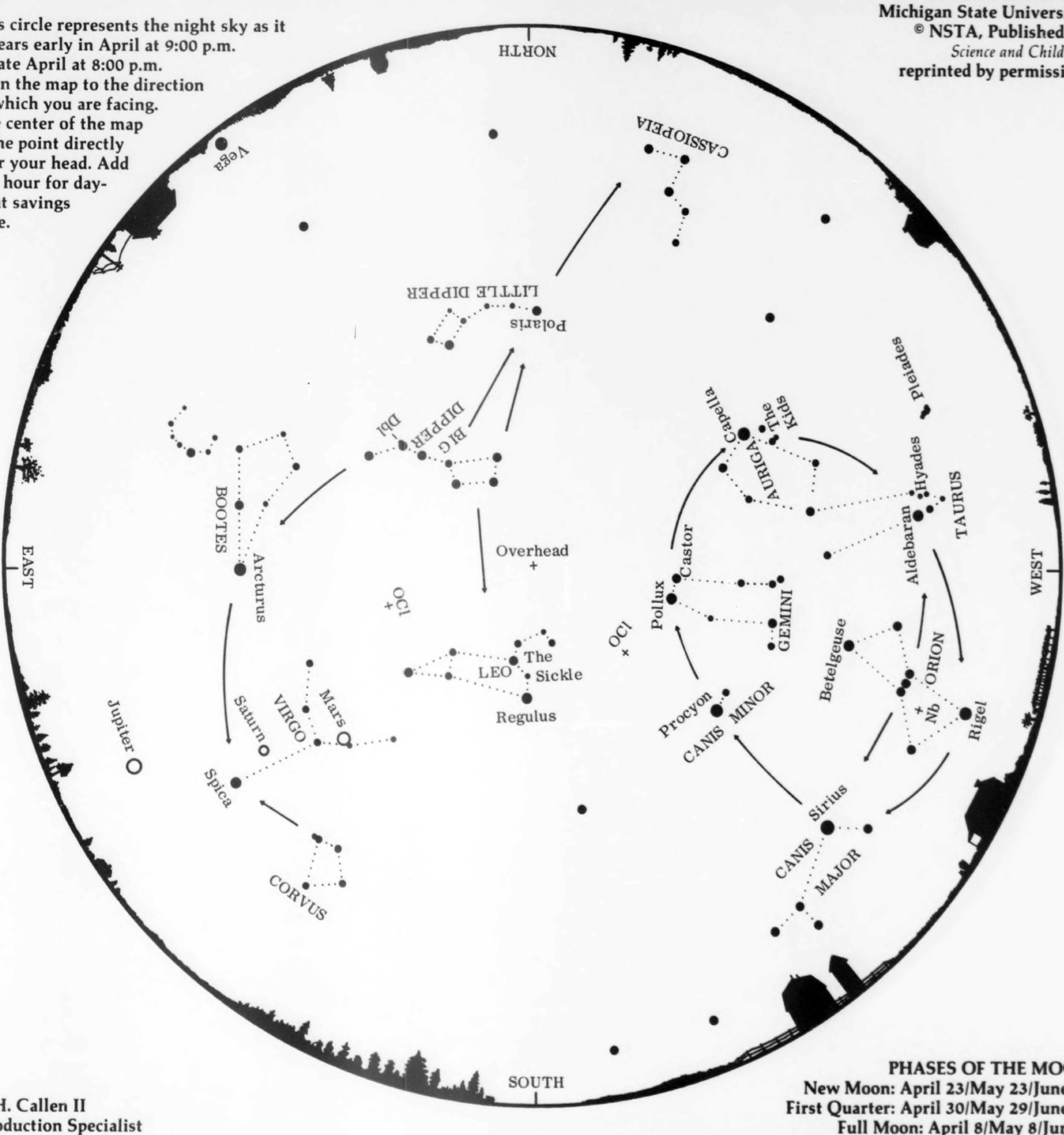
Krupp, E.C. 1979. *In Search of Ancient Astronomies.* Garden City: Doubleday and Company.

Smithsonian Exposition Books. 1981. *Fire of Life: The Smithsonian Book of the Sun,* New York: W.W. Norton and Company.

Spring 1982 Sky Map

This circle represents the night sky as it appears early in April at 9:00 p.m. or late April at 8:00 p.m. Turn the map to the direction in which you are facing. The center of the map is the point directly over your head. Add one hour for daylight savings time.

Sky map by
D. David Batch
Abrams Planetarium
Michigan State University
© NSTA, Published in
Science and Children
reprinted by permission


NORTH
CASSIOPEIA
Vega
LITTLE DIPPER
Polaris
BIG DIPPER
Dbl
BOOTES
Arcturus
EAST
Overhead
OCl
LEO
The Sickle
Regulus
Jupiter
Saturn
VIRGO
Mars
Spica
CORVUS
Capella
The Kids
AURIGA
Pleiades
Hyades
Aldebaran
TAURUS
WEST
Castor
Pollux
GEMINI
OCl
Betelgeuse
ORION
Nb
Rigel
Procyon
CANIS MINOR
Sirius
CANIS MAJOR
SOUTH

T.H. Callen II
Production Specialist
Albert Einstein Spacearium

PHASES OF THE MOON
New Moon: April 23/May 23/June 21
First Quarter: April 30/May 29/June 28
Full Moon: April 8/May 8/June 6
Last Quarter: April 16/May 16/June 14

With late winter and new spring skies still full of bright stars, now would be a good time to take your students outdoors to learn a few of the more familiar constellations in a new way—the way that they are seen by other peoples of the Earth. The constellations, or star pictures, that we are most familiar with have their origins in the mythologies of ancient Greece and Rome. There are a variety of other interpretations as well; we will consider some of them here.

Traditional mythology shows Gemini to be the twins Castor and Pollux who sailed with Jason and the Argonauts to seek the Golden Fleece. To the Indians of Mato Grasso, Brazil, the twins are two sacred flutes given to them by the Sun. The Sun also taught the Indians songs and dances to go with the flutes. The bright stars Castor and Pollux are sound holes near the lower end of the flutes.

In some cultures only part of a larger constellation is used—for example, the Pleiades star cluster in Taurus, a beautiful naked-eye grouping. In classical mythology, they are sometimes referred to as being the maiden Europa, kidnapped by the god Jupiter, who had turned himself into a white bull. The Dyaks of Surawak believe that the Pleiades are rice stars, the grain introduced to them in a boiled form by Si Kera, the sky-dweller. When they saw these stars in the sky, it was time to plant. The harvested rice was then kept in a storehouse made from the traditional constellation of Pegasus, which was set by map time.

The last example is perhaps the most easily recognizable star picture—Orion, the Hunter. The beliefs of Arnhem Land, Australia, show how different parts of the picture play different roles. Orion's belt of stars becomes three fishermen, and their fishing line is his hazy sword. The fainter stars in the area are the fishermen's children, while their wives are in a canoe marked by Taurus' Pleiades cluster. For further reading, see Natalia Belting's *The Stars Are Silver Reindeer* (Holt, Rinehart and Winston, 1966).

New Book from NASM

Bleriot XI: The Story of a Classic Airplane

by Tom D. Crouch

Fifth book in the series *Famous Aircraft of the National Air and Space Museum*

FAMOUS AIRCRAFT OF THE NATIONAL AIR AND SPACE MUSEUM
5
BLERIOT XI
The Story of a Classic Aircraft

The Bleriot XI made the first flight across the English Channel and became one of the most significant and influential of all European pioneer airplanes. It was enormously popular, but it did have technical problems. The author traces the evolution of this plane and examines how the defects were discovered and corrected. The restoration of the Bleriot XI, which took place at the Paul E. Garber Preservation, Restoration, and Storage Facility, is also vividly described. Richly illustrated with historical photographs, the book also has a full chronology, an appendix of all surviving Bleriots, a list of all aircraft types manufactured by Bleriot Aeronautique between 1900 and 1914, and an appendix describing problems faced by the pilots of these pioneer machines.

100 pp. 129 b&w illus. 8½ x 11 paper, $8.95 (shipping/handling $1.75)

The cover painting for the book, by John F. Amendola, Jr., was commissioned by NASM. An 11 x 14 print of the painting sells for $.50 in the Spacearium Shop.

To order this book and to obtain free information about the National Air and Space Museum's other hardbound and paperback books and posters on aviation and space subjects, write to Program Coordinator, Dept. AS-481, Room P-701, National Air and Space Museum, Smithsonian Institution, Washington, D.C. 20560. When ordering, please include handling and shipping charges.

Student Artists and the Space Shuttle

The Space Shuttle marks the beginning of a new age in space transportation and exploration. This exhibit is composed of 50 pieces of artwork by 6th, 7th, and 8th graders from nine District of Columbia public schools. The collection records students' impressions of the Space Shuttle as a machine and the astronauts view of Earth from the Shuttle's cockpit. Students worked in a variety of media including pencil, pastels, tempera, and acrylic paints.

This exhibit will be open until June 1, 1982, and is located in the Space Hall Gallery.

Teacher Resource Center
Located near the Educational Services Division of NASM, the Center is designed for the educational community and makes available a wide variety of air- and space-related teaching materials. Teachers may preview materials and develop their own classroom teaching aids. For an appointment or more information, call Mary Anne Thompson on (202) 357-1504.

New Exhibits at NASM

Jacqueline Cochran—World Record Holder

This new exhibit honors aviation pioneer Jacqueline Cochran who, at the time of her death, held more speed, altitude, and distance records than any pilot in aviation history. Cochran received her pilots license in 1932 and just six years later was named the outstanding female pilot of the year. In 1938, she won the Bendix Trophy, racing Los Angeles to Cleveland in just over 8 hours, 10 minutes. During World War II, Cochran was instrumental in organizing the Women Airforce Service Pilots (WASPs) and was named as its director.

The *Jacqueline Cochran—World Record Holder* exhibit consists of historical photographs, medals, trophies, and awards she won. Also included is one of her flying suits, her WASP uniform, and a film showing highlights of her career. This exhibit is located on the second floor of the Museum in the Pioneers of Flight Gallery.

National Air and Space Museum
Smithsonian Institution
Washington, DC 20560
Room P-700

Non-Profit Org.
U.S. Postage
Paid
North Branford, CT
Permit No. 12